Montana Department of Transportation

Surveying Manual

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Surveying Manual

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Department of Transportation

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Table of Contents

Chapter One — General

Introduction 1-1
- Description of Surveying 1-1
- Chapter Summaries 1-1

Maintenance and Updating of Manual 1-2

Assistance 1-2

Public Relations 1-2
- Importance 1-2
- Property Owners 1-2
- Media 1-3

Metric Measurements 1-3

Effective Date 1-3

Chapter Two — Survey Datums and Coordinate Systems

Vertical Datums 2-1
- NGVD 1929 2-1
- NAVD 1988 2-1
- Other Vertical Datums 2-1
- Monumentation 2-2
- Perpetuation of Bench Marks 2-2
- Requests for Vertical Control Data 2-2

Horizontal Datums 2-2
- Station and Distance 2-2
- Control Traverse Datum 2-3
- State Plane Coordinates 2-3
  - Latitude and Longitude 2-3
  - NAD-27 Coordinates 2-3
  - NAD-83 Coordinates 2-3
  - NAD-83 Single Zone 2-4

Chapter Three — Surveying Equipment, Measurements and Signing

Equipment 3-1
- General Instrument Care and Servicing 3-1
  - Operator's Manual 3-1
  - Routine Care of Equipment 3-1
  - Vehicular Transport 3-2
  - Casing and Uncasing 3-2

Field Transport 3-2
Set-ups 3-2
Field Adjustments 3-2
Major Adjustments 3-3

Equipment Descriptions 3-3
Transits 3-3
Theodolites, Automatic Total Stations and Manual Total Stations 3-3
Tribrachs 3-4
Electronic Distance Measuring Equipment 3-5
Traversing Equipment 3-6
Leveling Instruments 3-7
Tripods 3-8
Level Rods 3-9

Measurements 3-10

Angular Measurements 3-10
Terms 3-10
Importance 3-11
Types of Equipment 3-11

Vertical Measurement 3-12
Importance 3-12
Planning 3-12
Methods 3-13
Differential Leveling 3-13
Single-Wire Levels 3-14
Double-TP Leveling 3-14
Three-Wire Leveling 3-15
Trigonometric Vertical Measurement 3-16

Linear Measurement with Tapes 3-17
Taping 3-17
Care and Maintenance of Tapes 3-18

Errors, Corrections and Precautions 3-18

Instrument Errors 3-18
Level Bubbles and Optical Plummet 3-19
Double Centering 3-19
Parallax 3-19

Personal Errors 3-19
Setting Up the Instrument 3-19
Setting Sights 3-20
Pointing 3-20
Measuring Angles 3-20
Readings 3-20
Analyzing Field Notes 3-20

Natural Factors 3-21
Differential Temperatures 3-21
Heat Waves 3-21
Phase 3-21
Refraction 3-21

Relationships Between Angular and Linear Measurement 3-22
Consistency 3-22

Inconsistency 3-22
Curvature and Vertical Refraction 3-22
Signing for Survey Crews 3-22

Chapter Four — Errors and Maximum Closures

Accuracy and Precision 4-1
Blunders and Errors 4-2
Blunders 4-2
Errors 4-3
Types of Errors 4-3
Sources of Error 4-4
How to Handle Errors 4-5
Compatibility with Previous Surveys 4-5
Maximum Allowable Errors 4-6
Levels 4-6
Bench Levels 4-6
Bench Marks 4-6
Other Levels 4-6
Traverses Closures 4-7
Control Traverses 4-7
Property Corner Tie Traverses (Secondary Traverses) 4-7
Radial (Side Shots) Ties to Property Corners 4-7
Bridge Surveys (Additional Right of Way Not Required) 4-7
Conventional Surveys 4-8

Chapter Five — Preliminary Surveys

Preliminary Field Review Report 5-1
Control Surveys 5-1
Planning and Research 5-2
Reconnaissance 5-4
Establishment and Numbering of Control Points 5-4
Abstract 5-6
Bench Levels 5-7
Maximum Vertical Error and Adjustment 5-7
Government Bench Marks Are Present 5-7
Government Bench Marks Are Not Present 5-8
Limited Number of Government Bench Marks 5-8
Control Traverses 5-8
Definitions 5-8
Instruments and Number of Positions Required for Control Traverses 5-10
Instruments Not Used for Control Traverses 5-11
Basis of Bearing and Origin of Coordinates 5-11
Horizontal Angular Measurements 5-11
Distance Measurement and Reduction to Horizontal 5-11

Angular Closure 5-12
Traverse Balance/Adjustment 5-12
Baseline 5-13
Establishment of Angle Points on the Baseline 5-13
Cross Sections and Profile 5-15
Topographic Features 5-15
Aerial Photography 5-17
General 5-17
Ground Control 5-17
Aerial Survey Procedures 5-18
Target Locations 5-18
Horizontal Control Points 5-21
Vertical Control Points 5-21
Check Cross Sections 5-24
Map Editing 5-24
Conventional Surveys 5-26

Chapter Six — Property Corner Ties

Public Land Survey System 6-1
General 6-1
Overview of the Development of the Rectangular Survey System 6-1
Property Corner Ties 6-5
General 6-5
Research 6-7
Field Search 6-8
Numbering 6-9
Consultation with Right of Way 6-10
Corner Tie Procedures 6-10
Monument Descriptions 6-10
Procedures 6-10
Closed Traverse 6-12
Side Shot From Two Control Points 6-15
Side Shot from One Control Point Using Two Different Backsights 6-15
Side Shot from One Control Point and a Point On Line 6-15
Existing Right-of-Way Monumentation 6-16
Ties to the Horizontal Control Points (600 Series) 6-16
Computation of Traverses To Property Corners 6-17
Computation of Side Shots 6-17
Corner Recordation Act of Montana 6-17
Information Required to Complete a Certified Corner Recordation 6-18
Recording of a Certified Corner Recordation 6-18

Bridge Surveys 5-26
Aerial Photography Utilized or Additional Right of Way Required 5-26
Aerial Photography Not Utilized and Additional Right of Way Not Required 5-27
Additional Surveys 5-28
Preliminary Survey Requirements 5-28
Project Manager's Recommendations 5-28
Submitting the Survey 5-28

Chapter Seven — Reserved for Global Positioning Systems

Chapter Eight — Reserved for Data Collectors

Chapter Nine — Construction Surveys

General 9-1
Purpose 9-1
Survey Methods 9-1
Management of Engineering Control Surveys 9-2
Assignment of Personnel 9-2
Planning 9-2
Bridge Surveys 9-3
Checking 9-3
Safety 9-3
Staking Authorization 9-4
Construction Survey Duties 9-4
Care of Surveying Equipment 9-5
Checking Plans 9-5
Cooperation with Contractor 9-6
Horizontal Control 9-6
Traverse Control 9-7
Establishing Centerline 9-7
Establishing Additional Control Monuments 9-7
Random Control Use 9-8
Centerline Control 9-8
Setting Centerline Control 9-8
On-Line Traverse Method 9-9
Control Method 9-9
Centerline Reference Points (RPs) 9-9
Staking Centerline 9-10
Vertical Control 9-10
When Established 9-10
Bench Mark Spacing 9-11

Permanent Bench Marks 9-11
Temporary Bench Marks 9-12
Marking Bench Marks 9-12
Leveling Accuracies 9-12
Vertical Control 9-12
Survey Monuments 9-12
Relocation of Bench Marks 9-13
Staking Right of Way 9-13
Clearing and Grubbing Stakes 9-13
Cross Sectioning and Slope Staking 9-14
Computer Output 9-14
Planning 9-16
Cross-Section Intervals 9-16
Terrain Considerations 9-18
Tolerances 9-20
Unusual Situations 9-20
Slope Staking with Total Station 9-20
Marking Slope Stakes 9-28
Fill Stakes 9-28
Cut Slope Stakes 9-28
Reconstruction 9-28
Road Approaches, Dikes, Etc. 9-28
Staking Borrow Pits 9-36
Finish Grade Stakes 9-36
Bridge Construction Surveys 9-39
Responsibilities 9-39
Department Responsibilities 9-39
Contractor Responsibilities 9-40
Checking and Inspection 9-40
Preliminary Procedure 9-40
State Plane Coordinates 9-41
Horizontal Control — General 9-41
Horizontal Control — Tangent Dry Land Structure 9-42
Horizontal Control — Dry Land Structure on Curve 9-44
Vertical Control — Construction Grades 9-44
Fill Settlement Check Elevations 9-45
Structure Settlement Check Elevations 9-45
Structures Involving Railroads 9-46
Construction Surveys for Small Drainage Facilities 9-46
General 9-46

Pipe Culverts 9-46
Concrete Box Culverts 9-47
Dikes and Ditch Blocks 9-47
Drop Inlets 9-47
Curb, Gutter and Sidewalks 9-48
Construction Surveys for Miscellaneous Items 9-48
Fence 9-48
Bin Walls and Retaining Walls 9-48
Traffic Control Devices 9-48
Utilities 9-49
Guardrail 9-49
Right-of-Way Monuments 9-49
Right-of-Way Reference Monuments 9-50
Right-of-Way Reference Post 9-50
Monuments Located During Construction 9-50
Comfort Stations 9-50

Chapter Eleven — Notekeeping

Survey Notes 11-1
Definitions 11-1
Importance 11-1
Uses 11-2
Keeping Notes 11-2
Elements of Notes 11-2
Title Page 11-2
Sketch, Notes and Diagrams 11-2
Record Information 11-2
Pointings, Observations and Measurements 11-3
Descriptions 11-4
Importance 11-4
Practice 11-4
Elements 11-4
Delineation 11-5
Delineation 11-5
Drawing Sketch Notes 11-5
Construction Surveys 11-6
Horizontal Control — Centerline 11-6
Cross-Section Notes 11-6
Major Structures 11-7

Minor Structures 11-7
Common Errors in Notekeeping 11-7
Plus and Minus Rods 11-7
Distance Out of Sequence 11-8
Catch Point Not Defined 11-8
Excavation without Centerline 11-8
Wrong HI 11-8
HI in Wrong Column 11-8
Decimal Points 11-8
Corrections to Notes 11-8
Data Transmittal 11-9
Disposition and Use of Notes 11-9
Handling 11-9
Indexing and Checking 11-9
Submittal 11-10
Sample Notes 11-10

Appendix A — Sample Notes

Appendix B — References

Appendix C — Glossary

Appendix D — Basic Trigonometry

Appendix E — Curves

Figures

Chapter Two

2-1 New NGS Vertical Control Marker 2-6
2-2 Sample NAVD88 Data 2-7
2-3 Sample NAVD88 Data 2-7
2-4 Sample NAVD88 Data 2-8
2-5 Sample NAVD 88 Data 2-8
2-6 Latitude and Longitude Projections 2-9
2-7 NAD-83 Single Zone — Points of Origin and Lines of Exact Scale 2-10
2-8 NAD-83 Single Zone — Correction Factors 2-11

Chapter Three

3-1 Relationships Between Angular and Linear Errors 3-23

Chapter Five

5-1 Reference for a Control Point 5-3
5-2 Typical Horizontal Control 5-5
5-3 Atypical Horizontal Control 5-6
5-4 Traverse Loop Connections 5-9
5-5 Establishment of Angle Points on the Baseline 5-14
5-6 Target Placement from an Obstruction 5-19
5-7 Best Times for Mapping Photos 5-20
5-8 Target Dimensions 5-22
5-9 Vertical Control for Mapping 5-23
5-10 Check Cross-Section Locations 5-24
5-11 Tie an Existing Conventional Survey to Newly Established Control Traverse 5-26
5-12 Preliminary Survey Requirements 5-29

Chapter Six

6-1 Principal Meridians and Base Lines 6-3
6-2 Standard Parallels and Guide Meridians 6-2
6-3 Township Layout 6-4
6-4 Section Numbering within a Township 6-5
6-5 GLO Method of Subdividing Sections 6-6
6-6 Summary of Secondary Traverses and Side Shot Procedures 6-11
6-7 Traverse to Tie and Section Corner 6-13
6-8 Property Corner Ties to Traverse 6-14
6-9 Corner Recordation Act 6-20
6-10 Certified Corner Recordation Form 6-23
6-11 Certified Corner Recordation — Example 1 6-26
6-12 Certified Corner Recordation — Example 2 6-27
6-13 Certified Corner Recordation — Example 3 6-28
6-14 Certified Corner Recordation — Example 4 6-29
6-15 Certified Corner Recordation — Example 5 6-30
6-16 Certified Corner Recordation — Example 6 6-31
6-17 Certified Corner Recordation — Example 7 6-32

Chapter Nine

9-1 Earthwork Request Form 9-15
9-2 Design and Earthwork Computation Process 9-17

9-3 00 Sections 9-19
9-4 Miscellaneous Cross-Section Problems 9-21
9-5 Roadway Channel Change Cross Sections 9-22
9-6 Overhang Cross Sections 9-23
9-7 Cross Sections for Remeasuring 9-24
9-8 Backslope Rounding 9-26
9-9 Grade Change 9-27
9-10 Slope Stake for Normal fill sections 9-29
9-11 Slope Stake for Fill Section with Safety Shoulder 9-30
9-12 Slope Stake for Normal Cut Section — Example 1 9-31
9-13 Slope Stake for Normal Cut Section — Example 2 9-32
9-14 Slope Stake for Normal Cut Section — Example 3 9-33
9-15 Slope Stake for Cut Section with Flat Bottom Ditch 9-34
9-16 Slope Stake for Daylight Section 9-35
9-17 Borrow Pit Cross Sections — Example 1 9-37
9-18 Borrow Pit Cross Sections — Example 2 9-38

Chapter Ten

10-1 Blank Form HYD-1 10-13
10-2 Form HYD-1 — Example 1 10-15
10-3 Form HYD-1 — Example 2 10-17
10-4 Form HYD-1 — Example 3 10-19
10-5 Form HYD-1 — Example 4 10-21
10-6 Form HYD-1 — Example 5 10-23
10-7 Form HYD-1 — Example 6 10-25
10-8 Form HYD-1 — Example 7 10-27
10-9 Example Form HYD-2 — Water Well Information 10-29

Chapter Eleven

11-1 Field Note Check List 11-11

Table of Contents

Chapter One — General

Introduction 1-1

Description of Surveying 1-1

Chapter Summaries 1-1

Maintenance and Updating of Manual 1-2

Assistance 1-2

Public Relations 1-2

Importance 1-2

Property Owners 1-2

Media 1-3

Metric Measurements 1-3

Effective Date 1-3

Chapter One
General

Introduction

This manual is written to provide statewide uniformity in surveying practices, to establish and maintain survey standards, and to improve the overall efficiency of the Department's survey function.

If the surveying requirements of this manual conflict with the requirements of contract documents, then the contract prevails.

Description of Surveying

Surveying is performed to determine the relative positions of points on or near the earth's surface. It involves making measurements and calculations to provide essential information needed for planning highway routes, acquiring land, designing and constructing highways, and other related activities.

Chapter Summaries

The manual is organized with eleven chapters and five appendixes. Chapter One is an introduction to the manual.

Chapter Two, Survey Datums and Coordinate Systems, addresses the datums and systems used as references for all surveys. It includes discussions of vertical datums, local coordinate systems, the Montana Coordinate System, and other related topics.

Chapter Three, Surveying, Equipment, Measurements and Signing, deals with general techniques for observations and measurements and common surveying equipment. The chapter discusses accuracy and errors associated with angular, linear and vertical measurements, as well as the care and use of theodolites, electronic distance measuring devices (EDMs), total stations, levels and other equipment.

Chapter Four, Errors and Maximum Closures, describes sources of errors, practices to minimize the effect of errors and the accuracy and precision required for different surveys.

Chapter Five, Preliminary Surveys, is about the planning and data gathering activities needed for reconnaissance and design. It has a section about traverse procedures and discusses both photogrammetry and conventional preliminary surveying.

Chapter Six, Property Ties, describes corner search and identification methods and options for tying them to the control traverse..

Chapter Seven is reserved for the Global Positioning System (GPS).

Chapter Eight is reserved for Data Collectors.

Chapter Nine, Construction Surveys, covers methods for project construction staking and establishing reference markers.

Chapter Ten, Hydraulic Surveys, defines the methods for making surveys for stream crossings, irrigation and other drainage facilities.

Chapter Eleven, Notekeeping, outlines the components of notekeeping and their importance to the completion and interpretation of the survey.

The five appendixes cover the subjects indicated by their titles:

- Sample Field Notes,
- References,
- Glossary of Terms,
- Basic Trigonometry, and
- Curves.

This manual is not intended to be used as a substitute for a surveying textbook. See Appendix B for a list of textbooks and other references.

Maintenance and Updating of Manual

Everyone who has access to this manual should review the content and format, and submit recommendations for improvements. The primary intent is to provide all field crews with standard procedures. All persons should feel free to make suggestions. These suggestions will improve the next edition. This manual will be updated periodically to keep it current. The suggestions can consist of drawings or notes in any form. Send the recommendations to the Photogrammetry and Survey Section in Helena.

Assistance

For assistance or answers to questions concerning interpretation of the manual or surveying practices, contact the Photogrammetry and Survey Section ***prior*** to the survey.

Public Relations

Importance

The Montana Department of Transportation is a public service organization, and each of its employees is a representative for the Department. Relationships with the general public, property owners, media, utility and railroad companies, governmental agencies, contractors, and fellow workers can have a beneficial or adverse effect upon a project.

The survey party is one of the most visible groups representing the Department, and their conduct on the job and contacts with the general public, property owners and media representatives in particular are of extreme importance in the maintenance of good public relations. Cultivate good relationships and do your best to avoid antagonistic encounters.

Property Owners

Project managers or their agents usually make the first contact with property owners while in the process of obtaining written permission to survey. However, during the course of actual survey

activities, the party chief and crew members have day-to-day contact with the landowner. The party chief is responsible to assure that landowners or their agents are informed prior to actual entry on properties.

In addition, the party chief has the responsibility to maintain the best possible working relationships with property owners. Prior to any surveying activity, every crew member involved should be thoroughly briefed on the information that can be released at that time and who should be contacted for a more detailed explanation.

Most of the questions that a surveyor is asked can be anticipated and discussed beforehand with the entire crew. The answers should always be as concise as possible without speculation or guesswork. In some cases, requests are made about which crew members have not been informed or on which they do not have the authority to act. In such cases, the surveyor should make certain that an adequate answer is given to the landowner as soon as practicable. He/she should contact the supervisor or other higher authority, obtain the answer, and give it to the property owner in person.

Media

It is not the responsibility of the party chief or crew members to discuss Department business with the media. If approached by media representatives, refer them to the district office for the information that they need. Throughout your contacts with media representatives, conduct yourself so as to maintain a good impression of the Department.

Metric Measurements

When conducting surveys using the metric system, all procedures and specifications given remain in force. The stated closures remain in effect. A conversion will be made. For example, if bench levels should close within 0.06 feet, the metric closure would be equal to 0.018 meters. This closure is rounded to the nearest millimeter. Total stations will be toggled to display meters. Coordinates and elevations will be computed in meters.

Effective Date

The requirements contained in this manual will become effective upon receipt. However, projects having certain phases of preliminary surveys completed will be governed by previous specifications. All new phases of a project will be surveyed using the requirements in this manual. For example, if bench levels are completed but the control traverse is not, the control traverse will be surveyed according the specifications in this manual.

Table of Contents

Chapter Two — Survey Datums and Coordinate Systems

Vertical Datums 2-1

NGVD 1929 2-1

NAVD 1988 2-1

Other Vertical Datums 2-1

Monumentation 2-2

Perpetuation of Bench Marks 2-2

Requests for Vertical Control Data 2-2

Horizontal Datums 2-2

Station and Distance 2-2

Control Traverse Datum 2-3

State Plane Coordinates 2-3

Latitude and Longitude 2-3

NAD-27 Coordinates 2-3

NAD-83 Coordinates 2-3

NAD-83 Single Zone 2-4

Figures

2-1 New NGS Vertical Control Marker 2-6

2-2 Sample NAVD88 Data 2-7

2-3 Sample NAVD88 Data 2-7

2-4 Sample NAVD88 Data 2-8

2-5 Sample NAVD 88 Data 2-8

2-6 Latitude and Longitude Projections 2-9

2-7 NAD-83 Single Zone — Points of Origin and Lines of Exact Scale 2-10

2-8 NAD-83 Single Zone — Correction Factors 2-11

Chapter Two
Survey Datums and Coordinate Systems

A datum is a quantity or set of quantities that serve as a reference or base for other quantities. A datum may be assumed, given, measured or otherwise determined.

For highways to be designed or constructed, the field measurements need to be referenced to vertical and horizontal datums. These two datums are independent of each other. If the same datums are used on all projects, the connections between projects can be easily made.

Vertical Datums

Elevations for engineering projects must be referenced to a single vertical datum so that adjacent projects will match. This datum can be based on a standard such as sea level, orthometric or an assumed elevation. Organizations use datums that best serve their needs; this has led to the use of many different datums throughout the State.

NGVD 1929

The majority of the work performed by the Department was referenced to the sea level datum. This datum was established by the United States Coast and Geodetic Survey (USC&GS) in 1929 and is called the National Geodetic Vertical Datum 1929 or NGVD 1929. The published lists of bench marks established before the mid-1980s are based on NGVD 1929. These lists are provided by the National Geodetic Survey (NGS), which is the successor to the USC&GS.

NAVD 1988

The NGS has been running new level circuits across the country that were used in a readjustment of the vertical datum. The new vertical datum is called the North American Vertical Datum 1988 or NAVD 1988. NAVD 1988 will include all of the existing NGVD 1929 bench marks and provide new elevations based on the NAVD 1988 datum. NAVD 1988 will be used on all projects where it is practical to do so.

Other Vertical Datums

When working on highway projects, be certain to use the same datum during construction that was used for design. The datum should always appear in the field notes and on the plan sheets. Attention to the datum is particularly important during the transition from NGVD 1929 to NAVD 1988.

Some urban projects may be tied to a local, city or county datum. If a local datum is used, the field notes and plans must clearly state the origin of the datum.

An assumed datum may be used on small, remote projects where the expense to connect to a known datum is not justified. The field project manager should verify that an assumed datum is

acceptable. When using an assumed datum, establish a bench mark (5/8-inch x 30-inch rebar with a stamped 2-inch aluminum cap) in the vicinity of the project. Give the bench mark an assumed elevation that is obviously not sea-level based, such as 500 or 1,000 feet. The cap is stamped "BM," a number, and the year. Do not stamp the elevation.

Monumentation

Monumentation for both USC&GS and NGS bench marks have varied over the years, and many of the original bench marks have been disturbed or destroyed. Most of the bench marks are bronze caps. The caps are either set in standard concrete monument posts or embedded in concrete headwalls, pavements or stone outcrops. The latest style of bench mark being installed by NGS is a stainless steel rod driven to substantial refusal and protected by a covered aluminum box. An example of the new NGS vertical control mark is shown in Figure 2-1 on Page 2-6.

Perpetuation of Bench Marks

The majority of level lines in the country run along highways or railroads because they provide easy access to the lines. Highway departments are major users of these level lines and major destroyers of bench marks through their construction activities.

The perpetuation of bench marks is in the best interests of the nation, the state, and the Department. The Department has the responsibility to protect and perpetuate all existing, published bench marks. It is the responsibility of the field project manager to preserve existing USC&GS, USGS and NGS bench marks. If a bench mark cannot be preserved, the field project manager will be informed and a temporary bench mark (TBM) will be established in the vicinity. The field notes will be forwarded to the Photogrammetry and Survey Section. The Photogrammetry and Survey Section will forward the field notes to the State's Geodetic Advisor. Refer to the sample notes in Appendix A. The notes must conform in all aspects. A blank Form 76-60 is included in Appendix A. The TBM will be stamped with the name of the BM and TBM. Standard field notes may be used instead of Form 76-60.

Requests for Vertical Control Data

The Photogrammetry and Survey Section of the Preconstruction Bureau maintains a computer data base of all current USC&GS and NGS bench marks. Copies of this data may be furnished upon request. Information about the USGS level data is not kept on file by the Department, but it may be obtained. Included at the end of this chapter are samples of the information that can be obtained from Helena. See Figures 2-2 through 2-5. The field project manager should request this information to ensure having the most up-to-date information.

Horizontal Datums

Station and Distance

Originally, the Department used the method of station and distance right or left to locate, design and construct its highways. This method is still in use and is referred to as a conventional survey. During the design phase of a project, this type of survey was computed on a local coordinate system by using the bearings of the centerline and the differences between stations.

Control Traverse Datum

The current control traverse procedure uses a local coordinate system, similar to the coordinate system for a conventional survey. The north-south orientation of the system typically is based on astronomic observations taken at one of the control points or existing plans. Grid north by definition remains fixed, while astronomic north changes at a rate of approximately one minute per mile east or west of the point of origin in Montana.

Local coordinate systems should always start with assumed coordinate values large enough so that no point tied to the project has a negative value. The assumed values will depend on the length and direction of a project.

State Plane Coordinates

Local coordinate systems do not take into account the curvature of the earth. This discrepancy is not apparent or critical for surveys of limited scope, but as the horizontal control is extended from the origin of the coordinates the discrepancy becomes more apparent and critical. If large areas are to be connected, a coordinate datum that takes into account the shape of the earth is necessary. State Plane Coordinates do take the shape of the earth into account.

The State Plane Coordinate System was developed in the 1930s to provide a common, statewide reference system so that all surveys could be on the same datum or easily converted to another state's datum. The system in theory was great but was not implemented in states like Montana. The problem was not with the system but with the existing control. To compute positions on state plane datum, survey ties to known control points are required. In Montana most of the older known control points are located on mountain tops, which made their use impractical.

Latitude and Longitude

Latitude and longitude (geographic positions) are earth-centered, angular measurements of position. Latitude and longitude measurements use degrees, minutes, seconds and decimals of seconds. Latitude is the north or south location of a point referenced from the equator. Longitude is the east or west location of a point referenced from the meridian that passes through Greenwich, England. For example, Lewistown, Montana, is located at approximately 47° 05' north latitude and 109° 20' west longitude.

While latitude and longitude are useful for navigation, they are not convenient for engineering work. State plane coordinates satisfy engineering needs much better than latitude and longitude.

NAD-27 Coordinates

The first State plane coordinate system was developed in the 1930s using the North American Datum of 1927 or NAD 27. NAD 27 uses the Clarke 1866 spheroid as a reference. Grid coordinates were in US Survey feet.

Latitude and longitude positions are projected from the earth's surface to a plane using either the Lambert conformal conic projection or the transverse Mercator projection. The Lambert conformal conic projection is used for states like Montana that tend to run long in the east-west direction. For states like Idaho that tend to run long in the north-south direction, the transverse Mercator projection is used. Diagrams of each type of projection are in Figure 2-6 on Page 2-9.

NAD-83 Coordinates

During the late 1970s and early '80s, additional, precise survey data was combined with the existing NAD-27 survey data in a complete readjustment. A new datum for the geodetic reference

system was selected that approximated the shape of the world, rather than just the shape of North America. This earth-centered ellipsoid is known as the Geodetic Reference System of 1980 or GRS 80. The computations of positions on this new ellipsoid are known as the North American Datum of 1983 or NAD-83.

Because different ellipsoids were used to develop NAD-27 and NAD-83, the latitude and longitude for a point computed under NAD-27 are different from the latitude and longitude for the same point computed using NAD-83. There is no precise way to convert from NAD-27 to NAD-83 because of the different ellipsoids used for each system. There is, however, software available that will give a very good conversion of NAD-27 to NAD-83 or vice versa.

NAD-83 Single Zone

Description. With the development of NAD-83, the State elected to develop a new State plane coordinate system. The old NAD-27 system consisted of three zones. The new NAD-83 coordinate system consists of one zone for the entire State. Grid coordinates are in meters, using the international foot of 0.3048 meters = 1 foot — not 0.3048006 meters = 1 foot.

The NAD-83 Single Zone has advantages and disadvantages. The advantages, especially for the Department, are that the State is covered by a single zone and all ground distances get smaller when converted to grid distances. The disadvantage is that the size of the correction is larger than before. However, the correction needs to be made regardless of the state plane system used, and there is a smaller chance of mistakes if the correction is always signed the same.

Points of origin and lines of exact scale for NAD-83 Single Zone are shown in Figure 2-7 on Page 2-10. Grid distances are computed from measured ground distances by applying correction factors. The final correction factor is called a combination factor or C/F and is derived from an elevation factor and grid factor. Figure 2-8 (Page 2-11) provides information about how the factors affect distance.

For a complete, legal definition of both the NAD-27 and NAD-83 systems, see 70-22-201 (MCA) for the State law establishing the Montana Coordinate System.

Use. The Montana Coordinate System has not been widely used by the Department in the past. Ties to NGS monuments would have been too time consuming, and the field survey methods did not warrant the use of the System. The deployment of the satellite-based Global Positioning System (GPS) greatly simplified obtaining known positions for conversion to NAD-83 coordinates. GPS will allow the Department to begin using the Montana Coordinate System.

Only the NAD-83 coordinate system will be used in Montana. All GPS projects for the Department will be based on the State Plane Coordinate System and will use only NAD-83 Single Zone coordinates.

The methods for rigorous computation of State plane coordinates from field measurements are not covered in this manual. The Photogrammetry and Survey Section will perform all final computations. Final, adjusted control traverse computations will be provided by this Section to other sections involved.

C/F Factor. The Photogrammetry and Survey Section will provide the combination factor or C/F that will be placed on each plan sheet. When laying out computed distances using the NAD-83 coordinates, the layout distance will be lengthened by dividing the computed distance by the C/F factor. The C/F factor will be designed to convert between grid and ground measurements for the local area to a precision of one part in 50,000 or more. This is greater than the precision of most field measurements.

Azimuths. NAD-83 grid north is by definition the same as geodetic north along the central meridian of 109° 30' west longitude. Grid north remains parallel to the central meridian throughout the zone.

Geodetic north, however, is the azimuth toward the rotational axis of the earth. The difference between grid north and geodetic north is referred to as the convergence angle. The convergence angle can be nearly four degrees at the east and west borders of Montana. This convergence factor is a function of the distance from the central meridian and can be computed for any given NAD-83 State plane coordinate. The convergence angle is useful for retracing previous surveys, such as GLO surveys. In addition, the angle is needed to convert astronomic observations to grid azimuths.

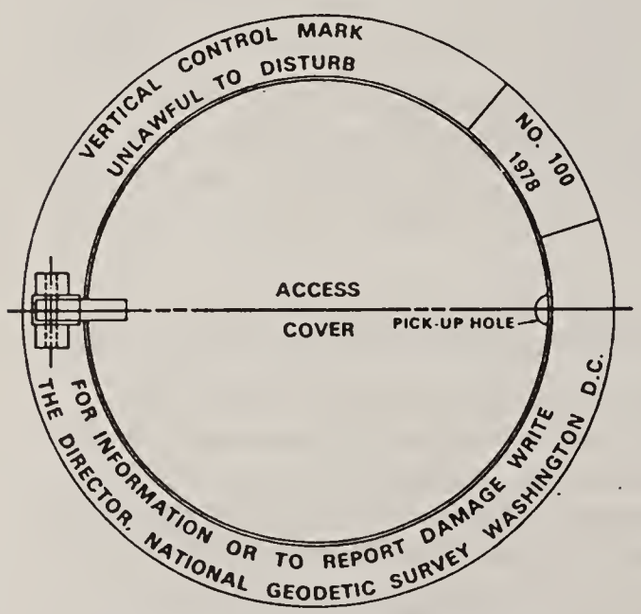
Coordinate Values. The NGS publishes NAD-83 State plane coordinates in meters only. The Montana Coordinate System specifies that the conversion factor to use is the international conversion of one foot equals 0.3048 meters. The Department will publish NAD-83 coordinates in meters and/or latitude and longitude.

Figure 2-1
New NGS Vertical Control Marker

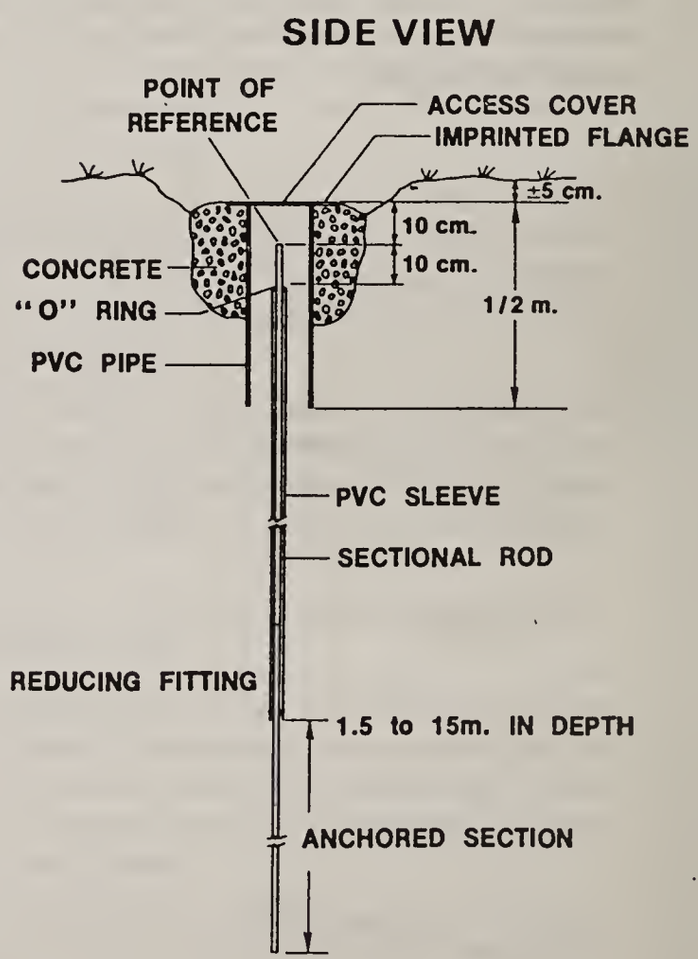
In 1978 the National Geodetic Survey (NGS) introduced a new, improved bench mark into the National Vertical Control Network. The reference point for the elevation is the top of a stainless steel rod. The rod is located inside a protective aluminum casement that bears the NGS logo and the stamped bench mark designation. Users can obtain access to the rod by lifting a hinged access cover.

The bench mark is designed to prevent near-surface soil movements, e.g., frost heave, shrinkage, swelling, from disturbing the mark. This is accomplished by encasing the rod in a lubricated sleeve to the depth of expected soil movement and by anchoring the rod in the soil below.

Top and side views of the bench mark are depicted below. Additional information about this mark can be obtained by writing to the Director, National Geodetic Survey, National Ocean Survey, NOAA, Rockville, Md. 20852.



BENCH MARK LOGO FLANGE & ACCESS COVER



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Survey

Figure 2-2

Sample NAVD88 Data

VERTICAL DESCRIPTION REPORT

Station Name: 12 RHM

PID	: TN0985	Latitude	: 483907.00000
County	: LINCOLN	Longitude	: 1153844.00000
State	: MT	Monument	: USGS
QSN	:	Monument Year	: 1963
Mark	: BENCH MARK DISK	Lst Rec Year	:
Stamp	: 12 RHM 1963	Lst Rec By	:
Quad	: 0481154	Lst Rec Cnd	:

COMPLETE DESCRIPTION:
***** SPECIFIC SETTING--IN DRILL HOLE IN ROC
***** MARK ORIGIN --- USGS
FROM LIBBY, MONTANA POST OFFICE, PROCEED 1.0 MILE NORTH ALONG STATE HIGHWAY 37 TO JUNCTION OF FOREST SERVICE ROAD 68 NORTH, THENCE 22.8 MILES NORTH ALONG ROAD 68 TO A Y-JUNCTION NORTHWEST TO LAFOE CREEK, IN THE SOUTHEAST 1/4 CORNER OF SECTION 6/TOWNSHIP 33 NORTH/RANGE 31 WEST, 27 FEET SOUTH AND 20 FEET EAST AND 6 FEET LOWER THAN THE ROAD, IN AN EMBEDDED ROCK OUTCROP.

Figure 2-3

Sample NAVD88 Data

VERTICAL DATUM NAVD88 FORM
MONTANA NGRS-NAD83_NGVD88

Station Name: 12 RHM
PID: TN0985

NAVD88 Ht in METERS	: 1209.779	NGVD29 Ht in METERS	:
NAVD88 Ht in Surv Ft	: 3969.083269	NGVD29 Ht in Surv Ft	: NO ELV
NAVD88 Ht in US Ft	: 3969.091207	NGVD29 Ht in US Ft	: NO ELV

Latitude - (DDMMSS)	: 483907.00000	Year Observed	: 1963
Longitude - (DDMMSS)	: 1153844.00000	Year Recovered	:
Monumenting Agency	: USGS	Date Adjusted	: 061591
Order & Class	: 3/0	Plot Number	:
State	: MT		

Figure 2-4

Sample NAVD88 Data

VERTICAL DESCRIPTION REPORT

Station Name: L 102

PID	: QX0241	Latitude	: 453806.00000
County	: GALLATIN	Longitude	: 1110253.00000
State	: MT	Monument	: CGS
QSN	:	Monument Year	: 1934
Mark	: BENCH MARK DISK	Lst Rec Year	: 1982
Stamp	: L 102 1934	Lst Rec By	: NGS
Quad	: 0451111	Lst Rec Cnd	: GOOD

COMPLETE DESCRIPTION:
ABOUT 3.3 MILES SOUTH ALONG THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD FROM THE FREIGHT STATION AT BOZEMAN, IN SECTION 25, T 2 S, R 5 E, 73 FEET NORTHEAST OF THE CENTER OF A ROAD CROSSING, 21 FEET EAST OF THE EAST RAIL, 47 FEET NORTH OF THE CENTER LINE OF AN EAST-WEST ROAD, 25 FEET WEST OF THE CENTER LINE OF A ROAD LEADING NORTH, 1.2 FEET WEST OF A METAL WITNESS POST, ABOUT 1 FOOT BELOW THE LEVEL OF THE TRACK, AND IN THE TOP OF A CONCRETE POST FLUSH WITH THE GROUND.
***** REPORT BY--NGS DATE--1982 CONDITION-- GOOD

Figure 2-5

Sample NAVD88 Data

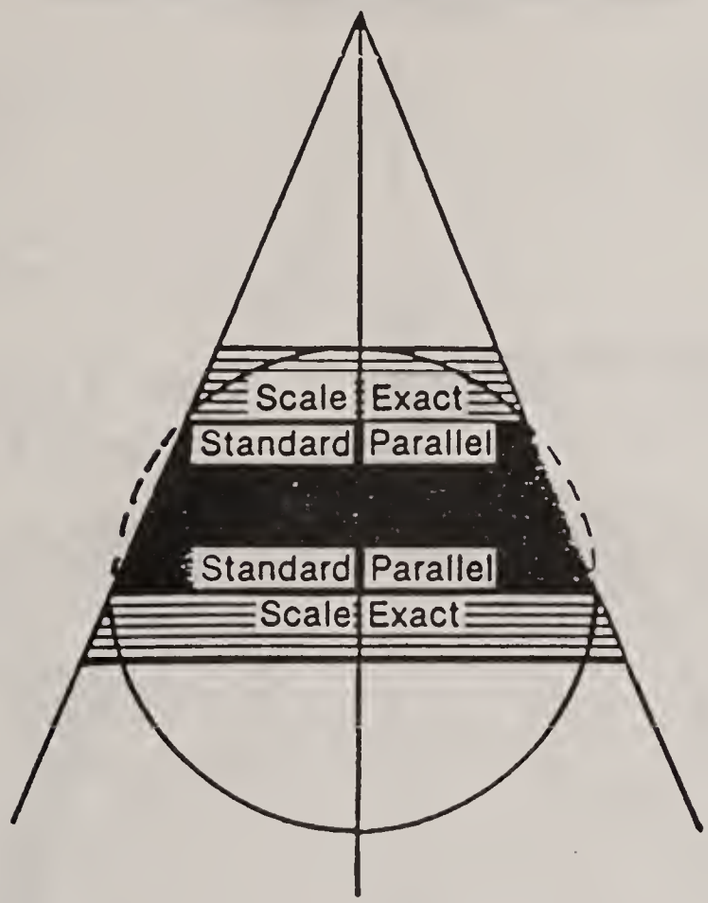
VERTICAL DATUM NAVD88 FORM
MONTANA NGRS-NAD83_NGVD88

Station Name: L 102
PID: QX0241

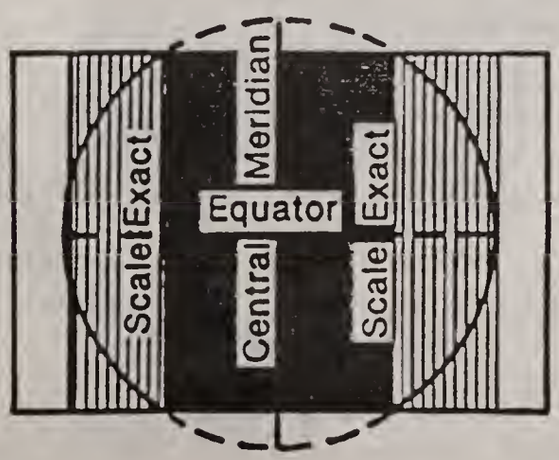
NAVD88 Ht in METERS	: 1539.440	NGVD29 Ht in METERS	: 1538.198 B
NAVD88 Ht in Surv Ft	: 5050.646066	NGVD29 Ht in Surv Ft	: 5046.571271
NAVD88 Ht in US Ft	: 5050.656167	NGVD29 Ht in US Ft	: 5046.581364

Latitude - (DDMMSS)	: 453806.00000	Year Observed	: *1960
Longitude - (DDMMSS)	: 1110253.00000	Year Recovered	: 1982G
Monumenting Agency	: CGS	Date Adjusted	: 061591
Order & Class	: 1/2	Plot Number	:
State	: MT		

Figure 2-6
Latitude and Longitude Projections



Lambert Projection — Cone Secant to Sphere
Defined by Two Standard Parallels and the Origin



Transverse Mercator Projection —
Cylinder Secant to Sphere
Defined by Central Meridian and Its Scale
Factor, and the Origin

Figure 2-7
NAD-83 Single Zone
Points of Origin and Lines of Exact Scale

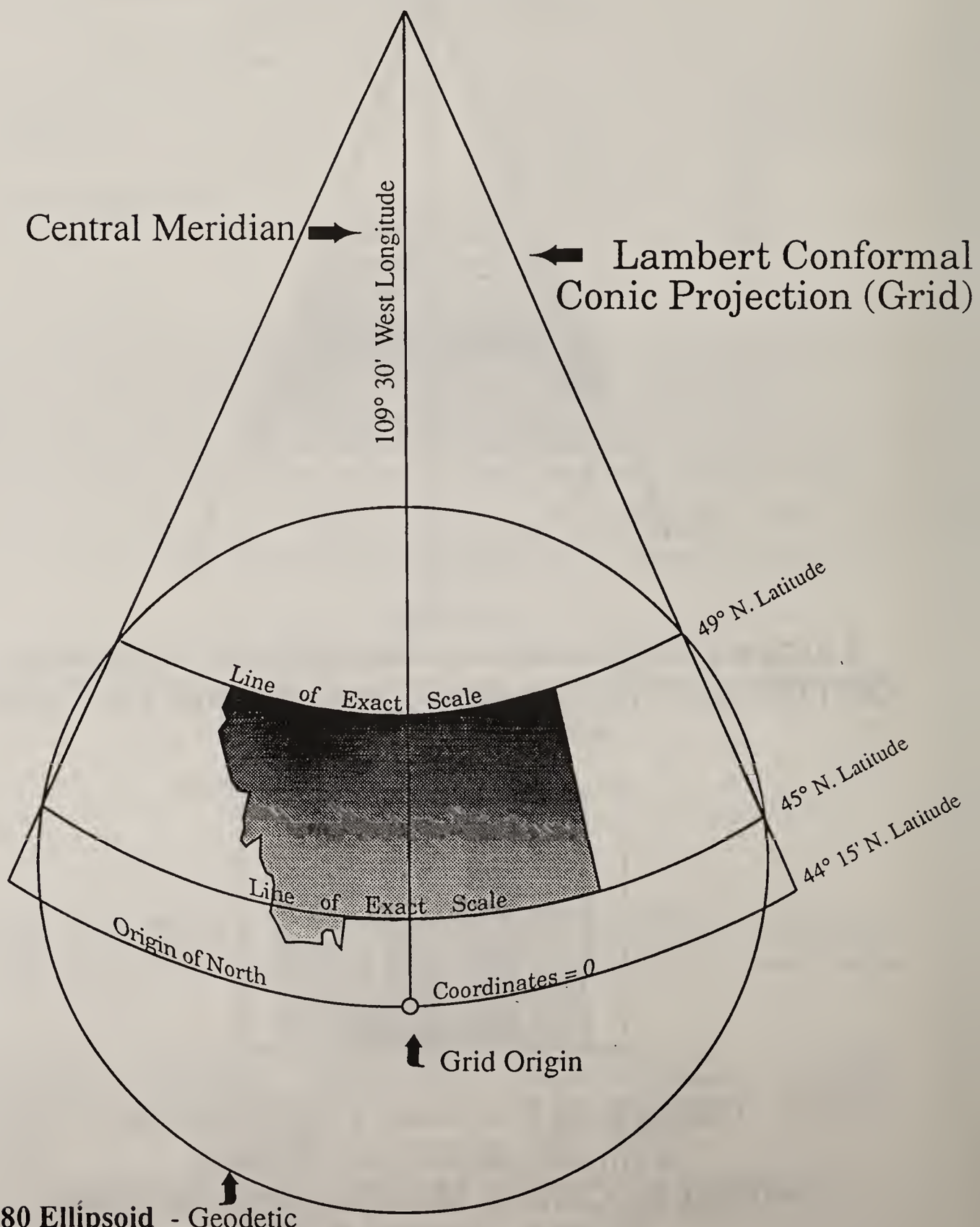
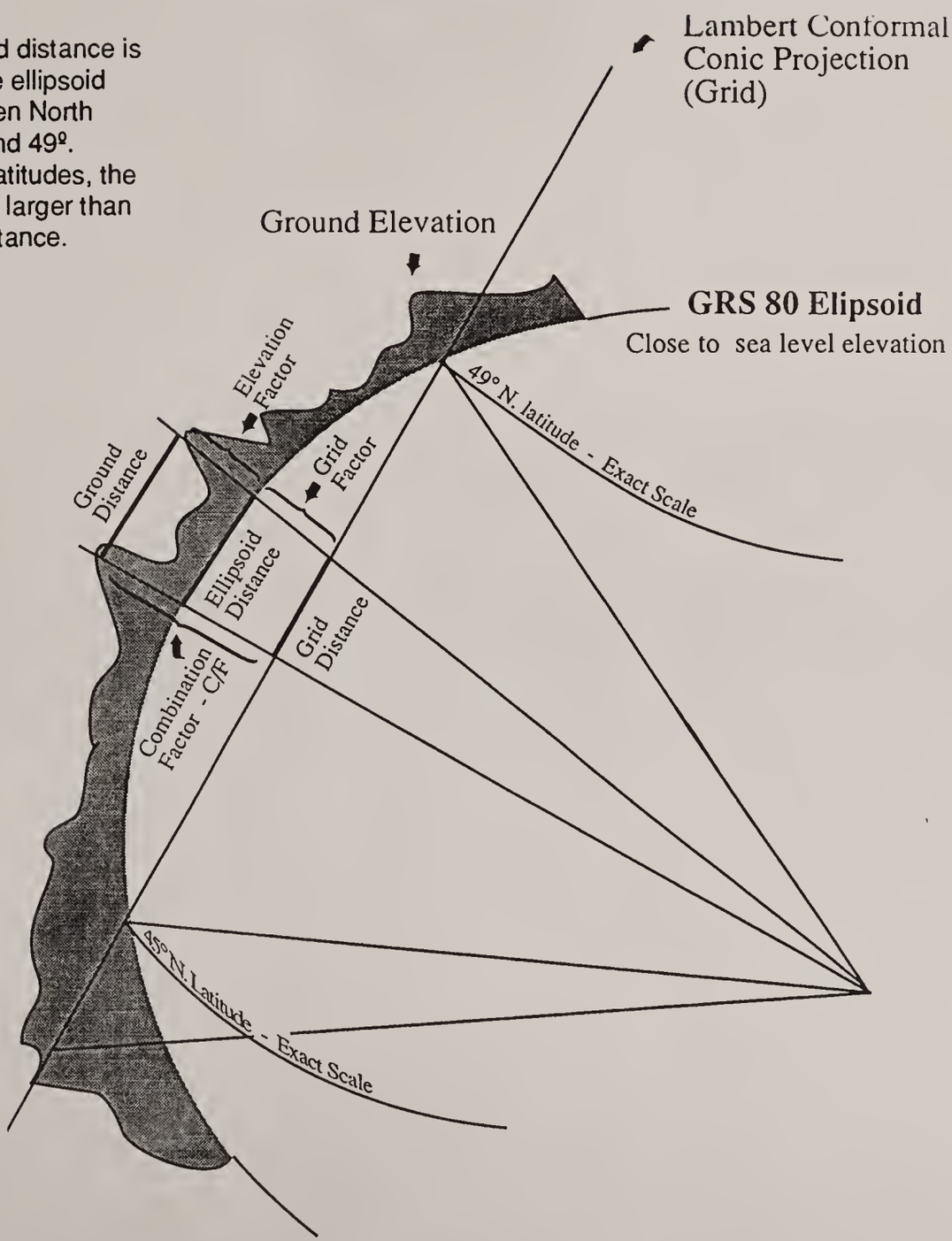


Figure 2-8
NAD-83 Single Zone
Correction Factors

NOTE: The Grid distance is smaller than the ellipsoid distance between North Latitudes 45º and 49º. Outside those latitudes, the Grid distance is larger than the ellipsoid distance.



Elevation Factor

A factor used to compute the difference between Ground distance and Ellipsoid (Sea Level) distance.

Grid Factor

A factor used to compute the difference between Ellipsoid (Sea Level) and Grid distance. Always less than one between lines of exact scale.

Combination Factor - C/F

A factor used to compute the difference between Ground distance and Grid distance. It is the product of the Grid Factor and the Elevation Factor. Always less than one for the Montana Single Zone

Table of Contents

Chapter Three — Surveying Equipment, Measurements and Signing

Equipment 3-1

General Instrument Care and Servicing 3-1
Operator's Manual 3-1
Routine Care of Equipment 3-1
Vehicular Transport 3-2
Casing and Uncasing 3-2
Field Transport 3-2
Set-ups 3-2
Field Adjustments 3-2
Major Adjustments 3-3

Equipment Descriptions 3-3
Transits 3-3
Theodolites, Automatic Total Stations and Manual Total Stations 3-3
Tribrachs 3-4
Electronic Distance Measuring Equipment 3-5
Traversing Equipment 3-6
Leveling Instruments 3-7
Tripods 3-8
Level Rods 3-9

Measurements 3-10

Angular Measurements 3-10
Terms 3-10
Importance 3-11
Types of Equipment 3-11

Vertical Measurement 3-12
Importance 3-12
Planning 3-12
Methods 3-13
Differential Leveling 3-13
Single-Wire Levels 3-14
Double-TP Leveling 3-14
Three-Wire Leveling 3-15
Trigonometric Vertical Measurement 3-16

Linear Measurement with Tapes 3-17
Taping 3-17
Care and Maintenance of Tapes 3-18

Errors, Corrections and Precautions 3-18

Instrument Errors 3-18
Level Bubbles and Optical Plummet 3-19
Double Centering 3-19
Parallax 3-19

Personal Errors 3-19
Setting Up the Instrument 3-19
Setting Sights 3-20
Pointing 3-20
Measuring Angles 3-20
Readings 3-20
Analyzing Field Notes 3-20
Natural Factors 3-21
Differential Temperatures 3-21
Heat Waves 3-21
Phase 3-21
Refraction 3-21
Relationships Between Angular and Linear Measurement 3-22
Consistency 3-22
Inconsistency 3-22
Curvature and Vertical Refraction 3-22
Signing for Survey Crews 3-22

Figures

3-1 Relationships Between Angular and Linear Errors 3-23

Chapter Three
Surveying Equipment, Measurements and Signing

Equipment

The procurement and maintenance of surveying equipment, tools and supplies are important parts of the Department's survey effort. Proper care in the use, storage, transportation, and adjustment of the equipment is a major factor in the successful completion of a survey. Lack of good maintenance practices can jeopardize the efficiency and accuracy of the survey.

It is the party chief's responsibility to train all crew members in the use of equipment and the maintenance of all surveying instruments, equipment, tools, and supplies. The Photogrammetry and Survey Section should be contacted for training and for discussing problems that arise during the survey. The field project manager is responsible for ensuring that all surveys conform with this manual.

General Instrument Care and Servicing

Surveying instruments are designed and constructed to provide years of reliable use. Although they are constructed for rugged field conditions, the shafts, spindles, pendulums, and electronics of precision instruments can be damaged by careless acts or inattention to the procedures for use, care and adjustment of the instrument.

Operator's Manual

An operator's manual is furnished with each new instrument. Among other information, the manual contains basic instructions for use of the instrument and describes recommended servicing and adjusting methods. Keep the manual with the instrument at all times. Study the manual before using the instrument, particularly before making field adjustments. If the manual is lost, stolen or damaged beyond use, obtain a replacement copy as soon as practicable.

Routine Care of Equipment

Before making the first set-up of the day, visually inspect the instrument for cracks, bumps, and dents. Check the machined surfaces and the polished faces of the lenses and mirrors. Try the clamps and motions for smooth operation (absence of binding or gritty sound).

Clean the exterior of the instrument frequently. Any accumulation of dirt and dust can scratch the machined or polished surfaces and cause friction or sticking in the motions. Remove dirt and dust with a clean, soft cloth or with a camel-hair brush. Clean non-optical parts with a soft cloth or clean chamois.

Clean the external surfaces of lenses with a fine lens brush and, if necessary, use a dry lens tissue. Do not use silicone-treated tissues because they can damage coated optics. You can breathe on

the lens before wiping it, but do not use liquids (oil, benzene, water, etc.) for cleaning. Do not loosen or attempt to clean the internal surfaces of any lens.

After an instrument has been used in damp or cold situations, use special precautions to prevent condensation of moisture inside the instrument. If you use the instrument in cold weather, leave it in the carrying case in the vehicle during non-working periods rather than take it into a heated room. If you store the instrument in a heated room overnight, remove it from the carrying case. If the instrument is wet or frost-covered, bring it into a warm, dry room, remove it from its case, and leave it at room temperature to dry out.

Vehicular Transport

Transport and store instruments in positions that are consistent with the carrying case design. For example, Wild theodolites should be carried and stored in an upright position. Many instrument cases indicate the position in which they should be transported.

Treat tribrachs, prisms and tripods with care. Carry them in their shipping cases or cushion them with firm polyfoam or excelsior-filled cases to protect them from jolting or vibrating excessively.

Casing and Uncasing

Before removing an instrument, study the way it is placed and secured in the case. Place it in the same position when you return it to the case. In removing the instrument from the case, carefully grip it with both hands, but do not grip the vertical circle standard or where pressure will be exerted on tubular or circular level vials.

Field Transport

Do ***not*** "shoulder" or carry a tripod-mounted theodolite, total station, or EDM. Always remove the instrument from its tripod for transporting and secure it in its field carrying case.

These precautions are necessary because the center spindle is hollow and relatively short. If you carry it horizontally while it is on the tripod, the alidade's weight is an excessive load for the hollow centerpiece to bear. You can damage the instrument if you ignore these precautions. Also, you can break the instrument fastener, causing the instrument to fall.

Set-ups

Whenever possible, select instrument stations where operation is not dangerous to the instrument operator, the party or the instrument. Select stable ground for the tripod feet. Do not set an instrument in front of or behind a vehicle or equipment that is likely to move. Take a safe route to all set-ups.

At the site, firmly plant the tripod with its legs spread wide. Push along the legs, not vertically downward. On smooth surfaces, use a tripod-leg restrainer to keep the legs from sliding outward.

Always have the tripod firmly set over the point before removing the instrument from its carrying case. Immediately secure the instrument to the tripod.

Never leave an instrument or its tribrach on the tripod without securing either to the tripod. Moderate pressure on the fastener screw is sufficient. Excessive tightening causes undue pressure on the foot screws and on the tribrach spring plate. Make sure the tribrach clamp is in the lock position.

Field Adjustments

Develop test procedures for eliminating random errors caused by lack of maintenance or adjustment and use the tests frequently. Include checks for the level vials, optical plummet, tripod adjustment, etc. In the field, make adjustments only when the instrument results are poor or require excessive manipulation.

Normally, you should check each instrument only where the best conditions for testing are possible. Only the adjustments described in the manual for the instrument should be made in the field or shop. Do not "field strip" (dismantle) instruments.

Major Adjustments

When an instrument has been damaged or otherwise requires major adjustments, it is sent to an authorized repair shop after Construction has been contacted. Unless otherwise directed, send all instruments requiring shop repair to the Construction Bureau. Include a written request for repair or replacement with the instrument. Indicate the type of repairs needed on the request. In the case of EDMs, describe the conditions under which the instrument does not function properly, that is, coldness, dampness, etc. Indicate the need for a "loaner" on the request.

If possible, the instrument should be "double cased" with its case packed inside a cardboard container. In many cases, the instrument can be sent to Helena with incoming Department personnel.

Equipment Descriptions

Specific surveying equipment is described below, along with its uses and any special precautions for its care.

Transits

Although theodolites have largely replaced transits, crews may use transits for close work, or as spare instruments in some cases. Most transits owned by the Department are equipped with 20- or 30-minute horizontal and vertical vernier scales. They are classed as repeating instruments, and fairly good close-order results can be obtained by turning sets of direct and reverse angles. Angular accuracies obtained are comparable to distance accuracies obtained by normal chaining practices.

Theodolites, Automatic Total Stations and Manual Total Stations

As with a transit, a theodolite or total station is used for measuring both horizontal and vertical angles. These instruments are more precise than transits. They can be classified as directional or repeating.

The horizontal circle of a direction instrument remains fixed during a series of observations. The direction of each foresight is read in relationship to the backsight.

A repeating instrument is designed so that successive measures of an angle can be accumulated on the graduated circle. The mean angle is the cumulative angle for all observations divided by the number of observations.

Procedures and Notes Format. This manual attempts to address the types of instruments used by the Department and the procedures for surveys using these instruments. Appendix A includes sample notes for some of the surveys conducted by the Department.

For the purposes of this manual, the terms automatic total station and manual total station need to be clarified. An automatic total station is defined as an instrument that reads and displays angles electronically. Examples are the Set 2 and Set 3 instruments. A manual total station is an instrument that uses an optical micrometer to read angles. Examples are the 3E and the 3F.

The directional method will be used exclusively for control traverses, ties to aerial photography control points, property corners, right of way, property controlling corners, and secondary control traverses. Either the directional or repeating method may be used for setting or layout of centerline, right of way or other control points.

Special Care. Although theodolites and total stations are ruggedly built, careless or rough use and unnecessary exposure to the elements can seriously damage the instruments. If they are handled reasonably, the instruments will provide consistently good results with a minimum of down time for repair or adjustment. Some general guidelines for the care of instruments are:

- Transport and store instruments in positions that are consistent with their carrying case design. Protect the instruments from excessive vibrations by carrying them in their shipping cases.
- Instruments should be removed from the case with both hands. Newer instruments are equipped with a carrying handle; use one hand to grip the handle and the other to support the base. Use one hand to continually support the instrument until the tribrach lock is engaged or the tripod fixing screw is secured.
- In all cases, total stations, theodolites and other instruments should be removed and re-cased for transportation to a new point. Do not "shoulder" an instrument or carry it horizontally. If the instrument has a carrying handle, you can use the handle for walking the instrument between set-ups.
- The collimation error of theodolites and total stations is determined by following the procedure outlined in the user's manual. If the collimation error is found to be consistently in excess of twenty seconds on the horizontal and thirty seconds on the vertical, the instrument should be adjusted.
- Never use a total station for a solar observation unless an approved solar filter is used. This will destroy an element in the EDM, plus damaging the eye of the observer.

Tribrachs

A tribrach is the detachable base of all theodolites, total stations, forced-centering targets, and most of the EDMs used by the Department. A Department tribrach is equipped with a bull's-eye bubble and optical plummet.

Special Care. The tribrach is an integral part of the precision equipment and should be handled accordingly. It should be transported in a separate compartment or other container to prevent damage to the base surfaces, bull's-eye level and optical plummet eye piece.

Over-tightening of the tripod fastener screw can put undue pressure on the leveling plate.

Adjustments. An out-of-adjustment tribrach can cause centering error. Each tribrach should be routinely checked for centering. Careful adjustment using a plumb bob is quite fast and should provide accuracy within 0.005 foot.

A more accurate method is to mark and rotate the tribrach 120 degrees at a time on a tripod. Before adjusting the optical plummet, adjust the bull's-eye bubble by using the instrument plate level bubble. For the first sighting, draw a line with a soft pencil on the tribrach head around the tribrach base. Carefully level the tribrach and mark the sighting point. Then rotate the tribrach 120 degrees, carefully set it in the pencil marks, re-level it, and mark the new sighting point. Then rotate a third time and repeat the procedure. If the tribrach is out of adjustment, the three rotational marks should form a triangle. Adjust the plummet to the center of the triangle using the capstan screws. Repeat the test to verify the instrument. If the tribrach is adjusted, re-check the tribrach until the adjustment stabilizes.

A tribrach adjusting ring is the preferred method. Place a tribrach on a tripod and the adjusting ring in the tribrach. Place the tribrach to be adjusted upside down on the ring. Look through the optical plummet and pick out a well-defined point on the ceiling. Turn the leveling screw on the bottom tribrach to center the optical plummet cross hair on the selected point. Rotate the tribrach on the ring

180 degrees. If the cross hair stays on the point when rotated, the optical plummet is in adjustment. If not, use the leveling screws on the bottom tribrach to eliminate one half of the error. Eliminate the remaining error with the adjusting screws on the optical plummet. Loosen one screw and tighten the opposite one. Repeat the procedure until the cross hair rotates on the point. The tribrach does not have to be level to perform the adjustment.

Electronic Distance Measuring Equipment

The development of electronic distance measuring equipment (EDMs) has had a profound effect on the surveying profession. Linear measurement, in any practical range, can be made speedily and accurately due to the development of short-, medium-, and long-range EDMs.

Most EDMs have approximately the same distance measuring accuracy when operated in accordance with the manufacturer's instructions, with the proper reflector systems. Every instrument has an inherent plus or minus error in every measurement plus a small error based on parts per million of the distance measured.

The primary differences among makes and models of EDMs are the distance they can measure with one or multiple reflector prisms, the time required to make a measurement, the ease with which they can be transported, set up and operated, and the additional functions that they can perform. For instance, the automatic total station incorporates angular measurement and automatic slope reduction to horizontal and vertical distances. The more sophisticated EDMs include built-in calculators that compute coordinate geometry. Electronic data collectors will be available as options for most automatic total stations.

This section covers the operating characteristics, limitations, and uses of EDMs. The section does not include specifics about the types of EDMs used by the Department. Operating and maintenance procedures are covered in the manuals supplied with each instrument. (EDMs used by the Department are classified as short- to medium-range instruments.)

Advantages. Some of the advantages of using an EDM are:

- a reduction in the time and crew size required for most measurements;
- the ability to measure across traffic or construction operations without inconvenience to others (motorists or construction crews) or undue hazard to the surveyors;
- the ability to measure to otherwise inaccessible points, such as across deep canyons or rivers;
- the ability to set many points from a relatively sparse control network, which is especially useful in construction staking;
- the ability to measure with increased precision and consistency; and
- the ability to quickly establish better supplemental control for construction staking.

Base Line Report. Test the EDM against an NGS baseline ***before*** commencing a control traverse. A test consists of obtaining and recording the measurements shown in Appendix A. A blank reporting form is included in the Appendix; you can photocopy it for your report. Prior to the test, check and adjust all optical plummets and tighten all tripods. At the baseline, record the shaded temperature and the station pressure. Complete the reporting form and the analysis of the measurements ***before*** leaving the baseline.

An analysis of the measurements consists of a comparison of the differences. The standard deviation of the instrument must be known. The standard deviation is given in the operator's manual. Refer to the sample Base Line User Report in Appendix A. As an example, 0 M-150 M marks show a difference of 0.0016. Is this difference acceptable? Generally, if the difference is less than or equal

to 2 times the standard deviation, the answer is yes. In this example, twice the standard deviation for this line would be equal to 2[0.005 + (3 x 150/1,000,000)] = 0.0109. The measured difference (0.0016) is less than 0.0109; therefore, the difference is acceptable. As an additional example, determine whether the difference of 0.0030 meters is acceptable for the line 0 M to 1400 M. The computation is 2[0.005 x (3 x 1420/1,000,000)] = 0.0185. The difference of .0030 is less than 0.0185, so the difference is acceptable. All six differences should be found to be acceptable. If not, repeat the test after checking the tripods and optical plummets. Send all base line reports to the Photogrammetry and Survey Section.

Traversing Equipment

Surveyors use a wide range of sights for a variety of survey operations. The main purpose of a sight is to provide a reference that is visible to the instrument operator. In this context, sights may be required for line, distance, or a combination of line and distance.

Line-Only Sight. The plumb bob string and Gammon reel is the old standard for short-distance sighting, particularly for establishing temporary points. Steadiness of the holder can be enhanced by the use of braces or any type of framework. Various types of inexpensive string-line targets are also available.

Range poles (prism poles) are the most common sight used by the Department. Range poles are made in several cross-sectional shapes, of various materials and in different lengths. Some are solid, some tubular, and others laminated. Most poles are approximately one inch in diameter.

The use of a bull's-eye rod level is essential when any type of range pole is used. Check and adjust the bull's-eye level prior to each day's use. The bubble is easily adjusted by using "Hold A Pole."

Force-Centering Targets. Tribrach-mounted traverse target sets or prisms are required for the control survey. The range poles mentioned above are not to be used for the control survey.

False Sights. Reflective surfaces, such as vehicle headlights, mirrors, window panes, etc., can cause false readings. Always recheck measurements that could be reflected from such reflector surfaces.

EDM Prisms. Each manufacturer of EDMs supplies special prisms and prism holders that are compatible with their equipment. The single lens, tiltable holder with provisions for direct connection on the top of a sectional or telescoping plumbing pole is the most common type used in most survey work. Such prism holders are generally equipped with a sighting target mounted above or below the prism to provide parallel sight between the sighting and measuring beams.

The maintenance of parallel sight is more significant in the accuracy of measurements as the distance is decreased. The use of the tiltable holder, with properly mounted target, maintains the parallel sight relationship, particularly in rough terrain. The surveyor should understand the necessity for parallel sights and know what the telescope aiming point is for the type of EDM being used.

EDMs have different methods of transmitting, receiving, and computing the light beam. Some light beams may be transmitted and returned to the instrument on the same path, while others travel to one side of the prism and return from the other side in a rectangular pattern. The pattern determines from which part of the prism the beam will be measured and thus affects the prism constant relationship between the EDM and prism being used. The position of the prism relative to the vertical axis of the sight also affects the prism constant. It is important that the proper prism constant is used; otherwise a systematic error will be introduced into all the measurements made between a particular EDM and prism. The best way to verify that true measurements will be made is to test the EDM and

prism on a calibration base line. The Department only uses prisms that have a minus 30 millimeter offset; the switch on the EDM must be set accordingly.

Care and Maintenance of Traversing Equipment. As with any survey equipment, proper care will extend the useful life of sighting equipment.

- Check the range pole bubble prior to each day's use. A quick check by fixing the rod in a tripod and rotating it 180 degrees will verify the adjustment.
- Check the bull's-eye bubble on the telescoping range pole using the "Hold A Pole."
- Treat forced centering target sets as any other precision equipment. Transport them in their carrying case in the proper compartments. Keep them clean and moisture-free to ensure maximum light return. Clean the reflective surface with a camel hair brush or soft lens tissue.

Leveling Instruments

Hand Levels. Most surveyors maintain a hand level as part of their personal equipment. They are useful in level runs for quick location of turn and instrument points. They are also quite useful for elevation checks during grading operations. As with any other level, the level bubble can become out of adjustment and should be checked periodically.

Abneys and Clinometers. Abneys have a protractor-type clinometer mounted on them. A cross hair and bubble can be seen when looking through the eyepiece, and they indicate when the level is horizontal. The Abney and clinometer can be used for direct leveling and for measuring approximate angles of slopes.

For use as a level, the Abney or clinometer is set to zero, and the level is used as the hand level addressed in the previous section.

Rhode's Arc. The Rhode's arc consists of a sighting tube mounted on the edge of a semicircular plate or arc. The arc is mounted vertically on a staff. The Rhode's arc is used for reducing measured slope distances to horizontal distances and differences in elevation.

The observer holds the arc on a point of known location and elevation, plumbs the staff, and sights on the target. The slope distance is taped and set on the vertical scale of the arc. The horizontal distance and difference in elevation can be read from gradations on the arc. The Rhode's arc is an accurate, effective tool for such tasks as cross sectioning and slope staking.

Automatic Levels. Automatic levels are the standard leveling instruments used on Department surveys. The principle of operation is essentially the same in all makes. The line of sight is maintained perpendicular to the direction of gravity through a system of prisms called a compensator.

These levels are fast, accurate and easy to maintain. Proper care and service are required to ensure continuous service and required precision. Do not disassemble instruments in the field. Attempt only those adjustments described in the instrument manual.

Review the previously stated guidelines for care of instruments. These guidelines are generally true for the proper care of pendulum levels, although levels may be shouldered. Additional guidelines are:

- Do not spin or bounce pendulum levels, as such movement can damage the compensator.
- Protect the level from dust. Dust or foreign matter inside the scope can cause the compensator's damping device to hang up.
- Check adjustment of the bull's-eye bubble. Make certain it remains centered when the level is rotated 180 degrees. Proper adjustment reduces the possibility of compensator hang-up.

- To check for compensator hang-up, lightly tap the telescope or lightly press on a tripod leg. If the instrument has a push-button release, use it. If the compensator is malfunctioning, send the instrument to the Construction Bureau for repair.

Circular Rod Levels. The circular (or bull's-eye) rod level is used for maintaining both level rods and sighting poles in a vertical position. An out-of-adjustment bubble used on sighting poles can cause errors in both angle and distance measurements.

Care and Adjustment of Leveling Instruments. Most of the comments dealing with care of instruments earlier in the chapter apply to all surveying equipment, including levels. Typically, only line of sight and bull's-eye bubble adjustments are needed for the automatic levels used by the Department.

The bull's-eye bubble is adjusted first. Center the bubble and rotate the telescope 180 degrees. The bubble should remain close to the center. If not, adjust the bubble one half of the distance to the center using an adjusting pin. Center the bubble, rotate the telescope 180 degrees. Repeat the procedure until the bubble remains close to the center when the telescope is rotated 180 degrees.

The line of sight is checked next and adjusted using what commonly is known as "pegging the instrument." Drive two hubs approximately 200 feet apart (hub "A" and hub "B"); drive them at a slight angle so that each has a definite high point. Set up at the midpoint between the two hubs and take readings on both hubs A and B; record the readings as "a" and "b." Then set up about 10 feet from hub B. Take readings on both hubs A and B again; record the hub B reading as "c" and the hub A reading as "d." The readings are used to determine whether the cross hair in the level needs to be moved. Do not move the instrument from the hub B location until you confirm that the line of sight is within tolerance:

- The true difference is a - b.
- The false difference is d - c.
- If a - b and d - c agree within 0.01 foot, no adjustment is needed.

If the difference is more than 0.01 foot, the cross hair needs adjustment. The correct reading, d', is equal to d + [(a - b) - (d - c)].

For an example of pegging the instrument, assume:

- a = 4.97
- c = 5.83
- b = 5.72
- d = 5.02

Then, a - b = -0.75 and d - c = -0.81. The difference between a - b and d - c is greater than 0.01 feet, so the cross hair needs adjustment. The correct reading is d' = 5.02 + [(-0.75) - (-0.81)] = 5.08 feet. With the level still near hub B, raise the cross hair from 5.02 feet to 5.08 feet. If the cross hair reticle has four adjustment screws, make sure to loosen one of the side screws first. Next, loosen either the top or bottom screw and tighten the other. Repeat this procedure until the cross hair reads 5.08 feet. Then, tighten the side screw. After making the adjustment, check it by repeating the peg method described above. The four readings may be estimated to the nearest 0.001 of a foot to keep random errors to a minimum.

Tripods

Tripods provide a fixed base for all types of surveying instruments and sighting equipment.

Types of Tripod Heads. Standardization by instrument manufacturers has created a need for only two types of surveyor's tripods: European and American.

The European tripod has a 5/8-inch diameter x 11 threads per inch instrument fastener that secures the instrument to the tripod head. The centering range is approximately 1-1/2 inches. European tripods have a wide-frame design, and those used by the Department are extension leg type.

The American tripod has a 3-1/2-inch diameter x 8 threads per inch head for fastening the instrument to the tripod. They are furnished with either fixed legs or extension legs. The American tripod is used with American-made transits and dumpy levels.

Care of Tripods. A stable tripod is required for precision in measuring angles. A tripod should not have any loose joints or parts that might cause instability. Some suggestions for proper tripod care are:

- Maintain firm snugness in all metal fittings, but never tighten them to the point where they will unduly compress or injure the wood, strip threads, or twist off bolts or screws.
- Tighten leg hinges only enough for each leg to just sustain its own weight when legs are spread out in their normal working position.
- Keep metal tripod shoes tight.
- Keep wooden parts of tripods well painted or varnished to reduce moisture absorption and swelling or drying out and shrinking.
- Replace the top caps on tripods when they are not in use or store the tripods such that the tops are not damaged.
- The most damage occurs to tripods when being placed into or taken out of survey vehicles. The life and usefulness of tripods can be significantly extended if compartments are constructed such that the tripod is not riding on or against other equipment.

Level Rods

Philadelphia Rod. The Philadelphia rod is the most widely used rod. It is made in two sliding sections held in contact by two brass sleeves. For readings seven feet or less, the back section is clamped in its normal clamped position. For greater readings, the rod is extended to its full length such that graduations on the front face of the back section are a continuation of those on the lower front strip. When extended, the rod is called a "high" rod.

Chicago Rod. The Chicago rod is made with three sliding sections held in contact by brass sleeves and two locking clamps. Although easier to transport than the Philadelphia rod, this rod is generally more difficult to read, and the extra locking joint is an extra source of calibration error.

Fiberglass Rod. Twenty-five-foot rods are widely used for slope staking and field topographic surveys. The added height reduces turns, and its relatively short sections make it easy to transport. Although they are made of strong, resilient fiberglass, they require specific care to remain serviceable and accurate. Use the following guidelines:

- Grit and sand can freeze the locking system of the slip joints. The close fit of these joints will not tolerate foreign matter. Do not lay a fiberglass rod in sand, dust, or loose granular material.
- Lower the sections as the rod is being collapsed. Do not let them drop. Dowels through the bottom of a section keep the section above from falling inside that section. Dropping sections during collapsing will loosen the dowels and jam the telescoping. It can also shatter the fiberglass around the dowel holes.
- When the slip joint goes bad, remove the rod from service.

Twenty-five-foot rods are ***not*** to be used for bench levels.

Checking Accuracy of Level Rods. Periodically check accuracy by extending the rod and checking foot marks throughout the length of the rod with an accurate tape or chain. Do this at the beginning of control level surveys. If the rod indicates a tendency to be off, it should be checked each time it is extended. A rod that is off by 0.01 foot will accumulate error but can show a perfect closure when the level circuit is closed on itself.

Care and Maintenance of Level Rods. Level rods should be maintained and checked as any other precision equipment. Accurate leveling is as dependent on the condition of the rods as on the condition of the levels. Reserve an old rod for rough work, such as measuring sewer inverts, water depths, etc. The care requirements common to all types of rods are:

- Protect rods from moisture, dirt, dust, and abrasion.
- Clean graduated faces with a damp cloth and wipe dry. Touch graduated faces only when necessary, and avoid laying the rod where the graduated face will come into contact with other tools, objects, matter or materials and become soiled.
- Do not abuse a rod by placing it where it might fall; do not throw, drop or drag a rod, or use it as a vaulting pole.
- Keep the metal shoe clean and avoid using it to scrape foreign matter off a bench mark or other survey points.
- If possible, leave a wet rod uncovered, unenclosed, and extended until it is thoroughly dry.
- Store rods either vertically (not leaning) or horizontally with at least 3-point support, in a dry place, and in their protective cases.
- Periodically check all screws and hardware for snugness and operation.

Measurements

Angular Measurements

Horizontal angular measurements are made between survey lines to determine relative directions of the lines. When horizontal distance measurements are applied to the derived direction, the relative position of a point is established. Horizontal angles are measured on a plane perpendicular to the vertical axis (plumb line).

Vertical angular are measured to determine the slope of survey lines from the horizontal plane (level line). When the vertical angle is applied to the slope distance, the horizontal and vertical distances may be calculated.

Vertical angles are measured on a plane passing through the vertical axis perpendicular to the horizontal plane. Zenith angles are used to facilitate the trigonometric calculations of horizontal and vertical distances. For zenith angles, the reference or zero angle is on the vertical axis directly above the instrument.

In the United States, the sexagesimal system of angular measurement is used. There are 360 degrees in the circumference of a circle. A degree is divided into 60 minutes (60'), and a minute is divided into 60 seconds (60") and decimals of a second.

Terms

The following terms are defined specifically for angular measurement as used in this manual. Their meanings may differ slightly in other contexts.

Pointing — A pointing consists of a single sighting and reading on a single object.

Observation — An observation is a single, unadjusted determination of the size of an angle. For example, an observation is made by subtracting the value of a pointing on a backsight from the value of a pointing on a foresight to determine an angle.

Mean — The mean is the final determination of the magnitude of an angle before adjustment. The mean consists of at least two observations.

Backsight (BS) — A backsight is a survey point that is used as an initial sight for orientation when measuring horizontal angles and directions.

Direction — A direction is the value of a clockwise angle between a backsight and any other survey point. The readings of each backsight are reduced to zero degrees, and the directions to the other survey points are computed from this survey point. Directional instruments usually are used to measure directions.

Setting the Circle — Setting the circle is the act of setting a specified horizontal reading while the telescope is pointed toward a backsight. Generally zero degrees, or the calculated "back azimuth," or a predetermined setting is used.

Direct and Reverse Readings — A direct reading is taken with the telescope in the upright position with the vertical circle on the left (left face). A reverse reading is with the telescope inverted and the vertical circle on the right (right face).

Position — Turning a position is the act of making two direct and two reverse pointings on each survey point to which a direction is required. For a direction instrument, the horizontal circle remains stationary for a given position but is reset for each new position. Notes for angles turned with a directional theodolite are usually grouped by position.

A complete position consists of two direct and two reverse pointings. More than one position may be required depending on the survey requirements.

Set of Repetitions — A set of repetition angles is a series of observations of the same angle, where each observation is accumulated on the horizontal circle of the instrument. Half a set is measured in the direct mode and the other half in the reverse mode.

Indirect Measurement — Indirect measurement of angles is made by "trilateration," where the angles are computed from horizontal distance measurements (usually by EDM) of the three sides of a triangle. Orientation of the triangle is established by selected sides whose directions are known or measured.

Importance

Determination of the direction of a line, azimuth or bearing is a fundamental requirement for establishing the horizontal position of one point and its relationship with any other point in the survey. If the relative positions of the end points are known, then the purpose of the survey is to establish usable survey points between them.

Distance and angular measurements are of equal importance in establishing point positions. Angular errors are by far the most difficult and expensive to isolate and correct. Analysis of a traverse closure error can sometimes reveal the types of errors and aid in their elimination.

Types of Equipment

Transits, theodolites and total stations are used for making angular measurements.

Vertical Measurement

A survey requires vertical measurement, in addition to linear and angular measurement. Vertical measurements establish the elevation of points in relation to a datum that extends through and beyond the project limits. In the coordinate survey, the horizontal position is described by X and Y coordinates and the elevation described by the letter Z. The complete coordinate description of a point is of the form X, Y, Z or Y, X, Z.

Vertical angular measurements are required to reduce slope measured distances to horizontal distances. Automatic total stations used by the Department are equipped with zenith sensing devices that provide for the reduction internally. These instruments display the operator's choice of slope, horizontal or vertical distance (difference in elevation).

Older manual total stations, such as the SDM-3E, measure the slope distance only and a theodolite is used to record the angular measurement. The slope reduction is computed from the zenith angle and slope distance. A correction for the earth's curvature and refraction may be applied in certain cases to determine the horizontal distance and difference in elevation.

Importance

The determination of accurate elevations is an extremely important part of the information required for the design of highway projects. Grade lines, drainage structures, and other highway features are designed in relation to existing and final elevations. Volumetric quantities are determined by preliminary (before) and final (as-constructed) cross sections.

The reliability of photogrammetric mapping and supplemental measurements derived from them are controlled by the accuracy of the horizontal position and elevation of all control points.

Due to its importance in all other phases of the project, vertical measurements to establish primary elevation controls are made at an early stage in the survey. As discussed in Chapter Five, differential levels are used to establish elevations for all traverse control monuments when feasible. These bench marks serve as the primary extension of the NGS datum through the project area. Subsequent, level loops between the control monuments, again by differential leveling, are used to establish bench marks for photogrammetric, preliminary, construction, or other control networks.

Planning

By the time a project survey is completed from preliminary through the construction phase, each bench mark will have been used many times to provide the base for vertical measurement. Proper planning in anticipation of the future uses of vertical control points (bench marks) is as essential as that required for the horizontal control. Some considerations for the placement of horizontal and vertical points are:

- location of the primary control (control traverse monuments);
- permanence (outside of anticipated construction limits — do not set in fence lines, next to trees or buildings);
- accessibility (on the right of way or other accessible lands);
- type of monument set — concreted monuments (permanent), rebars (semi-permanent), and wooden hubs (temporary);
- spacing (BMs generally at 1,000 feet), keeping in mind that the horizontal control points can be used as bench marks — in other words, projects may not require the traditional bench marks if all control points have elevations;

- estimated final design grade; and
- visibility.

Methods

Vertical measurements are made directly or indirectly. The choice of the method and its procedures depends on present and future accuracy requirements and the relative cost. Consider these items in selecting the method and procedures:

- the precision of the survey should be compatible with the accuracy of the controlling monuments,
- the type of equipment available, and
- the future survey needs.

Direct Vertical Measurement. This method refers to the direct reading of elevations or vertical distances. Some common types of direct elevation determinations are altimeters, differential levels, and profile levels.

Indirect Vertical Measurement. Indirect vertical measurements require the use of calculations to determine elevations or vertical distances. Trigonometric levels is one example.

Prior to the development of total stations, almost all vertical measurements on highway projects were made by differential leveling. Trigonometric measurements using total stations can be a cost effective method of making vertical measurements, but some precautions need to be taken.

Tolerances for the various types of control points and other elevation points are cited in the section describing the work.

Differential Leveling

Equipment. The standard instrument for all differential leveling is the automatic level.

The Department primarily uses Philadelphia two-section, Chicago three-section, and fiberglass leveling rods. Each type of rod has its particular advantage under certain field conditions. Any rod used should be clean, "tight," and have properly indexed scales. Check slip-joint rods for index periodically.

Instrument Setups. The following guidelines pertain to instrument setups:

- Do not waste time by deeply embedding tripod feet. Settlement is usually insignificant. Avoid setups on hot pavement or in spongy or muddy soil.
- Set turning points so that the backsights and foresights for each setup are approximately equal. This compensates for curvature and refraction and for systematic errors in the instrument.
- Use sight distances that best fit the terrain and are the most comfortable for the instrument operator. Sight distances should not exceed 250 feet.
- In steep terrain, place "turns" and instrument setups so they follow parallel paths (not along the same line).
- Take an extra turn rather than try to read the bottom or top of the rod.
- Periodically test the level to be certain the pendulum compensator is working. Point on a "natural" sight with the telescope over a foot screw and turn the screw back and forth or lightly tap the instrument. If the cross hair dips and returns to its original position, the compensator is working properly.

Turning Points and Bench Marks. Use the guidelines below:

- Set bench marks in stable, protected locations. Do not set spikes in utility poles more than 4 inches above the ground because they may be hazardous to utility workers. Wooden stakes and hubs should be used only as temporary bench marks. The control traverse monuments should be used as the primary bench marks.
- Make each turn stable and with a definite high point. If a TP does not have a prominent point, mark the exact point with keel or paint.
- All bench mark descriptions should describe the bench mark and give its location.

Rod Reading. Use the following for reading rods:

- Eliminate parallax before any readings are made.
- Do not deliberate over readings. Read and call them out in a moderate rhythm.
- Whenever possible, plumb the rod with a rod bubble. In the absence of a rod bubble, the rod-person should slowly rock the rod toward and away from the instrument. The observer reads and records the lowest reading. The rod must be set on a sharp or rounded projection; otherwise the rod will rise as it is rocked and will result in a false reading.
- Avoid low, ground-skimming shots where refraction might become pronounced. Also, avoid sighting close to obstructions that might diffract the line of sight — if possible, no closer than 1 foot from an obstruction.
- Read and record to the nearest 0.01 of a foot.
- Record exact splits always high or low.

Single-Wire Levels

Single-wire leveling is the most common and widely used method of vertical measurement. With proper attention to procedures, third-order accuracy may be achieved with single-wire leveling. Some of the methods will be described in general terms only. Detailed procedures may be found in publications such as those listed in Appendix B. Sample notes showing a level loop associated with a control traverse is shown in Appendix A.

Normally, single-wire notes are reduced to HIs and elevations as the survey progresses. To check the elevations of BMs that are turned through, differences in elevations are calculated. In the case of a level loop, the algebraic sum of the backsight and foresight should equal the ending elevation of a BM minus the starting elevation of a BM. See the sample notes in Appendix A for examples. Side shots will not be used to establish any TBMs, BMs, elevations for aerial photography, or control traverse monuments.

Simple, single-wire level runs should be straight-line adjusted, but with careful attention to the sign. The closing error is prorated to each new bench mark, and/or traverse control point, between two consecutive, controlling bench marks:

$$\text{Adjustment to a BM} = \frac{\text{(Vertical Error) x (Number of FS to the BM)}}{\text{Total Number of FS}}$$

Double-TP Leveling

This technique uses two parallel, independent foresight and backsight TPs for each HI. It is usually used for third-order leveling or very special circumstances. Each pair of TPs is set, if

possible, at an appreciable difference in elevation (preferably one-half foot or more). They are also set a few feet apart so the level will have to be rotated slightly between the two rod readings.

From each set-up, single-wire plus shots are read on both backsight TPs; minus shots are read on both foresight TPs. Notes are kept separately for each line of levels. The adjusted elevations from the two lines of TPs are averaged.

The system has some advantages in that the HI is determined from each of the two lines and mis-reading or mis-leveling blunders can be isolated immediately. However, the system is time-consuming and both lines are run in the same direction, which may not cancel systematic errors. There is also a danger in misreading the initial backsight and the final foresight.

Three-Wire Leveling

With this leveling technique, the cross hair and both stadia hairs are read to the nearest thousandth of a foot. (The system is widely used with an invar rod and the readings taken to the nearest thousandth of a yard.) Stadia intercepts of plus and minus shots are accumulated. The running totals are constantly monitored so balance can be maintained between totals of foresight and backsight distances. The backsights and foresights should be balanced within 32 feet. Sample notes are included in Appendix A.

This technique is generally preferred over previously described methods when more precise elevations are required. There probably are few reasons for the Department to use three-wire leveling. Its special requirements are below.

Instruments. The Department uses levels with either a stadia ratio of 0.3 to 100 or 1.0 to 100. For precise levels, the 0.3 to 100 ratio is preferred because the stadia hairs are nearer the optical center. It also permits a greater elevation difference between the level and the TP while keeping all three cross hairs on the rod.

Most of the Department's instruments are equipped with the 1.0 to 100 stadia ratio, and their use is also acceptable. Spacing of the setups and TPs will need to be adjusted for the instrument used.

Rods. The Department does not have invar rods. It is recommended that the best Philadelphia rod available be used on these surveys. Even new rods should be checked upon delivery, as some rods have been found to be off.

Instrument and Rod Checks. Before starting each day's run, test the level for collimation error. Test at or near the first setup of the day and record the process in the field notes. If the error exceeds 0.01 foot in 200 feet, the instrument should be adjusted. Any time the instrument has a severe jolt or bump, re-test it.

Check the rod in the raised position to ensure there is no index difference above and below the slip joint. Recheck the rod each time it is extended.

Setups. Keep all sights within 200 feet. When rejected readings average more than two in every ten, shorten the sighting distance.

Turning Points and Bench Marks. Railroad spikes, boat spikes, wooden stakes or hubs may be used for TPs. Permanent BMs should be numbered so they can be identified when recovered.

Establish all bench marks prior to leveling. Check all found monuments that are to be incorporated in the level line for stability.

Rod Readings. Plumb the rod with an accurate rod level. Do not use the wave method for three-wire levels. Start the rod reading with the top stadia wire, and progress to the bottom wire. Estimate readings to a thousandth of a foot. Read at moderate speed, without deliberations. Do not turn or pick

up the instrument until the note keeper has verified the spread. If the spread between top and center wire and bottom and center wire exceeds 0.005 foot, re-read all three wires. The original readings should be crossed out and new readings entered on the next line. In some cases, it may not be necessary to provide all checks as shown in the sample notes.

Reruns. The highest order of accuracy required will normally be met by a single run of three-wire levels between existing NGS benchmarks. If the run fails to close within the tolerance specified, one of several problems exists. Some of the problems are:

- There may be a discrepancy between the elevations of the beginning and closing bench marks. This should be the first possibility checked. Be sure that the government elevations data sheet is the last published for the two points. (There is a possibility that one or both of the bench-mark elevations have been readjusted.) If the latest information was used, carry the survey to the next NGS benchmark.
- The benchmarks may be on different lines.
- You are mixing NGS and USGS bench marks.
- You made a reading or calculation error.

If the possibilities above do not account for the discrepancy, the run should be re-leveled in the opposite direction. Re-leveling at a different time of day may be preferable.

Trigonometric Vertical Measurement

Trigonometric vertical measurement is a procedure in which vertical differences in elevation are computed from slope distance and zenith angle measurements. HIs and HSs are required.

The development and continuing refinement of zenith-sensing total stations are making rapid changes in the use of trigonometric vertical measurements. These instruments are of varied vertical-angle accuracy, and certain procedural restrictions must be applied.

Use. Trigonometric levels are often the most practical (and economical) method for establishing elevations in rolling to steep terrain. It is useful for many types of surveys. Some of these are:

- reconnaissance surveys,
- control for aerial photography,
- check levels for long differential lines,
- establishing low order bench marks by precise vertical traversing (when accuracy is difficult to attain at reasonable expense by differential leveling),
- slope staking, and
- cross sectioning.

Accuracy Attainable. The accuracy that can obtained from trigonometric levels depends on the individual accuracies of the following:

- error in the zenith circle,
- error in the measurement of the HI and HS,
- amount of curvature and refraction in the distance measured, and
- error in the slope distance.

Error in the Zenith Circle. The error in the zenith circle must be eliminated. Manual total stations, when using trigonometric levels to determine the elevation of photo control points, require a direct and reverse zenith angle. Trigonometric levels for topographical mapping requires only a direct zenith angle, but the error in the zenith circle must be determined and adjusted or compensated for prior to any topographic work. Refer to the manual supplied with the instrument or contact the Photogrammetry and Survey Section for assistance with this adjustment.

Error in the Measurement of the HI and HS. It is important that these errors do not occur. If the HI or the HS is measured incorrectly, the error probably will go unnoticed. The vertical error of the foresight point will be in error by the measured error in either the HI or HS. If the EDM is at a different height from the theodolite, or the zenith angle is measured to a point different than the one the distance was measured to, then all four heights must be recorded.

Error Due to Curvature and Refraction. This source of error can be eliminated only by reciprocal zenith angles. Reciprocal zenith angles consist of observations at each end of the line. Reciprocal zenith angles must be used for all photo control points if the observation is from a single control point. Curvature and refraction must be compensated by:

- setting switches in the total station (approximate),
- reciprocal trigonometric levels, or
- mathematical calculations (approximate).

It is important that the switch setting be noted in the field notes. Automatic total stations should have the switches set to "on" to compensate for curvature and refraction. Manual total stations should have the switch set to "on."

Error in the Slope Distance. This error is the random error associated with the EDM, not a mistake made in recording the slope distance. This random slope distance error seldom has a significant effect.

Distance. The amount of curvature and refraction is a function of distance, latitude, and atmospheric conditions. The effect is not proportional. For example, the curvature and refraction associated with a distance of 1,000 feet is 0.026 foot, but at a distance of 3,000 feet it is 0.185 foot.

The sample notes in Appendix A include information to determine the elevation of a photo control point. It is important that all the information shown in the samples be included in your field notes.

Differential Versus Trigonometric Levels. Differential leveling is the preferred method for obtaining elevations. Differential levels are used exclusively for the establishment of bench marks and elevations of traverse control monuments. Trigonometric levels may be used to obtain elevations of photo control points only if differential methods are too time consuming.

Linear Measurement with Tapes

Surveyor's tapes are available in various lengths, of different materials, and with many methods of graduations. Although EDMs have replaced tapes for long measurements, every crew should have both metallic and non-metallic tapes available.

Taping

Use the following guidelines when taping:

- Keep the tape stretched straight between two points. Do not allow it to bend around bushes, trees or boulders.

- Do not let wind blow the tape off line when plumbing for a point.
- When the distance between the two end points is longer than the tape, ensure that the intermediate point(s) are aligned with the end points.
- Do not become careless when plumbing for a point.
- Keep the correct tension on the tape. Tapes of 100 feet or less require 10 pounds of tension when supported along their entire lengths. Light steel tapes stretch 0.01 to 0.02 foot in 100 feet if the tension is increased to 20 pounds.
- Avoid sag.
- Apply the appropriate temperature correction factors for the taped measurements. Tapes are calibrated at 68° F. They expand or contract 0.0000065 foot per foot for each degree of change above or below 68 degrees.
- Ensure that the tape is the correct length (see below).

Care and Maintenance of Tapes

Tape reels for metallic or fiberglass tapes save time and help prevent damage to the tape, particularly if used in construction or heavy traffic areas.

Routine care extends tape life. The following are basic guidelines for care of metallic tapes:

- After the day's work, clean and dry tapes that are soiled. In wet weather, lightly oil, then dry tapes before storing. Avoid storing in damp places.
- Clean rusty tapes with fine steel wool and cleaning solvent or kerosene. Use soap and water when tapes are dirty or muddy. To prevent rust after cleaning, oil lightly and then dry the tapes.
- Use chaining clamps to avoid kinking the tape.
- Do not place a tape where it can be stepped on or run over, unless the tape is flat, taut, and fully supported on a smooth surface.
- Leave the tape on the reel unless you are making a series of pulls that are full-tape lengths. Do not wind tapes excessively tight on their reels, as it can cause unwanted stresses.
- Keep the tape straight when in use. When dragging a tape between points, watch carefully for loops forming. When pulling a slack tape, a loop can develop into a kink and easily break the tape, especially when going down hill.

Errors, Corrections and Precautions

Factors that might influence the occurrence of errors can be roughly divided into five classes: instrument, personal, natural, random, and systematic. The first three types of errors are covered below. Random and systematic errors are addressed in Chapter Four.

Instrument Errors

Make adjustments at regular intervals and particularly before starting work on a control survey. Make the adjustments under the most ideal conditions available, normally in the highway yard or shop on an overcast day. Instruments requiring major adjustments should be serviced at an authorized repair shop.

Level Bubbles and Optical Plummet

Normal measuring procedures do not compensate for maladjustment of either the plate bubble(s) or the optical plummet. These components must be checked more frequently than others.

On control traverse projects, check the optical plummet. Check the plate bubbles routinely on each setup. If you detect error, set the bubbles for the mean of the error or adjust the bubble. Refer to the manual supplied with the instrument.

Double Centering

Double centering compensates for lack of adjustment of almost all components of the instrument and should be standard practice for all angles measured (or laid off) with a transit, theodolite or total station. Double centering consists of a minimum of two observations (one direct and one reverse); the mean position is then used.

Parallax

Parallax occurs when the focal point of the eyepiece does not coincide with the plane of the cross hairs. The condition varies for each observer because the focal length depends in part on the shape of the observer's eyeball. Parallax is also a major concern in the optical plummet.

Check for parallax every time you begin to operate a new instrument or one that has been operated by someone else. Check the optical plummet on every setup, particularly if the HI is significantly different from the last setup.

To check for parallax, focus the telescope on some well-defined distant object. Slowly move the head back and forth, about an inch from the eyepiece, while watching the relationship of the object to the cross hairs. If the object appears to move, parallax exists.

To eliminate parallax, rotate the knurled eyepiece ring until the cross hairs are the thickest and blackest, re-focus the instrument, and check for parallax as described earlier. If parallax still exists, repeat the procedure.

Personal Errors

Setting Up the Instrument

Use the guidelines below for setting up an instrument:

- Be sure the tripod is in good condition and all hardware is snugly fitted.
- Push the tripod shoes firmly into the ground. Do not stamp on the tripod feet. Pressure should be parallel to each leg.
- Place the legs in positions that will require a minimum of walking around the setup. In windy conditions, additional stability can be achieved if one leg is set downwind.
- On hillsides, set one leg uphill.
- If the ground is soft or muddy, drive 2-inch x 4-inch wedges into the ground to support the tripod legs. Use duck boards to support the instrument operator.
- Be sure the instrument is exactly over the point.
- Check the optical plummet after the instrument is set up and just before moving to another point. If the instrument has moved, check the angle just measured.
- Recheck the instrument level. The bubble should remain within one graduation when the instrument is smoothly turned through one circle (if the instrument is shaded).

Setting Sights

When tribrach-mounted targets are used, take the same precautions as when setting up an instrument. With this equipment, "forced centering" between targets and theodolite (and vice versa) greatly decreases the effects of plumbing errors in traverse closures. Forced centering is especially beneficial in short-course traverses. Forced centering is the traverse procedure whereby backsight, instrument point and foresight are "leap-frogged."

Once a tribrach is set over a point, it stays mounted on the tripod over that point for all uses. The instrument and sights are transferred from point to point without disturbing the tribrach setup. This is standard procedure for the control traverse.

Use these guidelines for setting sights:

- Always check a sight before picking up to see that it has not moved.
- When setting a pole sight, plumb it with a precision equal to that required for the total survey. A twenty-second error results from a sight that is one-tenth out-of-plumb and 1,000 feet away.
- If a sight is set near ground level, check the line of sight for obstructions or for excessive heat waves. On very warm days, ground-level sights are not advisable.

Pointing

Tangent Screw Use. When moving onto a target, always make the last turn of the tangent screw clockwise. Clockwise movement increases the tension on the loading springs. A final turn counterclockwise releases tension and the spring can hang up, causing a "backlash" error.

Cross Hair Use. Sight each object with the same part of the cross hair, preferably near the center of the field of view. This practice minimizes small residual adjustment errors.

The human eye can estimate the center of a wide object more accurately than it can line up two objects. For this reason, different pointing techniques should be used depending on the type and apparent size of the sight in the telescope.

When pointing on narrow sights, such as the center of a red and white target or distant range pole, straddle the sight with the double cross hairs. When pointing on wide sights, such as a lath or range pole at close range, split the sight with the single cross hair.

Measuring Angles

Measure angles as rapidly as comfortably possible with a uniform rhythm. Take the first reading at an object, rather than fidgeting with the tangent screw trying to improve the pointing. Too much pointing time increases the probability of error through instrument settlement or atmospheric changes. Speed should not, however, be cultivated at the expense of good results. Accuracy is more important than speed.

Readings

Carefully read and call out each reading to the recorder. Call out the entire reading each time so any large blunders are caught. Have the recorder repeat the reading to the instrument operator after it is recorded.

Analyzing Field Notes

Many recording errors and inconsistencies can be caught by carefully analyzing the observations. These items should be checked in the field by the recorder and then rechecked in the office. Examples are:

- Spreads between the seconds of direct and reverse readings should be consistent and in the same direction throughout the set.
- The sums of the direct and reverse zenith angles should be consistent.
- When the direct and reverse observations of a position are in different minutes, be sure the average second value is coupled with the correct minutes value.

Natural Factors

Differential Temperatures

Bright sunlight striking certain parts of the instrument may cause differential expansion of the metal components of the instrument, resulting in small errors.

Heat Waves

On a hot day, heat waves can cause distortion of lines of sight near a reflecting surface. Control traverses should be halted if excessive heat waves are present.

Phase

If a sight is not evenly lighted on both sides, the instrument operator tends to point toward one side. This phenomenon, called "phase," can be reduced by using a target with a flat surface pointed directly toward the instrument. The targets attached to the prism are useful in reducing phase.

Refraction

When light waves pass from a medium of one density into a medium of a different density, the rays change in direction (bend). The change in direction is called refraction. Because sight lines are light rays, they are refracted, or bent, by changes in the atmosphere, causing small errors in angular measurement.

Normally, the lateral refraction is insignificant in most surveys, but its effects can be further minimized by understanding and avoiding situations producing the largest refraction of line of sight. Some of these situations are:

- When the sun shines on a barren, dark surface, the surface warms relatively quickly. This warms the air, and if calm, it produces a column of warm, light air rising from the surface. Examples are:

  + dark, freshly plowed fields lying between lighter colored areas of growing crops,

  + clear areas between heavy forests, and

  + large bodies of warm water between land areas.

- Open valleys bordered by bluffs on either side can result in refraction. If a line must pass over a valley, set the observation points as far back from the edges of the valley as possible.
- Air tends to layer parallel to the slopes of embankments or the base of foothills.

When refraction is probable in angles to be measured, or is suspected in angles that have been measured, recon the survey area and plan station locations to avoid the problem conditions listed above.

Relationships Between Angular and Linear Measurement

Consistency

When a survey involves both angular and linear measurements, maintain consistency (if practicable) between the precision of angular measurements and that of the linear measurements. In other words, the errors in angular measurements should approximately equal the errors in linear measurements. For example, if distances are to be measured to a precision of 1/10,000, measure the angles to the nearest 20 seconds. (A 20-second error will result in an error of 0.10 foot offset in 1,000 feet.)

The table in Figure 3-1 provides a detailed tabulation of angular errors and their corresponding linear errors and ratios of precision.

Inconsistency

Often it is not practical to maintain the same precision in angular and linear measurements. For instance, when performing a theodolite and cloth tape topography survey, the precision of angular measurement will greatly exceed the precision of linear measurement. This is satisfactory because the increased accuracy of the angular measurement does not require any additional effort or time; that is, it is just as easy to read a theodolite to the nearest minute as opposed to some lesser precision (say 1/1000 or 3 to 4 minutes).

Curvature and Vertical Refraction

Zenith angles measured for horizontal and vertical reduction of long lines require curvature and refraction corrections.

Automatic total stations correct vertical and horizontal measurements for curvature and atmospheric refraction, using average atmospheric conditions when the correction is turned on. At longer distances (3,500 feet or more), the trigonometric solution of a triangle formed by the mean of reciprocal distance measurements and the mean of reciprocal zenith angles negates the need for curvature and refraction correction and provides a better data set than that provided by the on-board correction factors.

Signing for Survey Crews

The minimum traffic control requirements for state and consultant survey crews are listed below.

- When surveying near active roadways:
  - + Crew members wear orange hats or hard hats and safety vests in accordance with existing safety policies.
  - + One "Survey Crew Ahead" or other acceptable legend sign is set up in each direction from the work site.
- When crews are working on or frequently crossing the highway:
  - + Two 48-inch by 48-inch "Survey Crew Ahead" signs, orange with black lettering, are set up on the right-hand shoulder at least 12 inches above the ground. The two signs are placed a minimum of 500 feet apart.
  - + A set of signs is used for each two-lane roadway.
  - + On multiple-lane, divided roadways, the signs are set up on the left- and right-hand sides of the lanes being worked on.

- If the survey chief thinks it is necessary, a 24-inch by 30-inch thirty-five miles per hour sign, white with black lettering, can be posted in each direction. The signs are needed so that law enforcement can enforce the posted speed limit. The survey chief needs to make sure the speed limit signs do not conflict with others in the survey area. If they do, temporarily cover the conflicting signs.
- The signs should not be more than one-half mile from the work site.

Additional signs, flaggers or traffic control devices may be needed because of narrow roadways, high traffic volumes, or limited sight distances. Use the additional measures if you or your supervisor think they are needed. If flaggers are required, refer to the traffic control signing in Standard Drawing 208.

Figure 3-1
Relationships Between Angular and Linear Errors

Angular Error	Corresponding Linear Error per 1,000 feet	Ratio of Precision
0.2 second	0.00100 foot	1/1,000,000
1.0 second	0.00485 foot	1/206,200
2.1 seconds	0.01000 foot	1/100,000
4.1 seconds	0.02000 foot	1/50,000
5.0 seconds	0.02420 foot	1/41,200
8.2 seconds	0.0400 foot	1/25,000
10.0 seconds	0.0485 foot	1/20,600
13.8 seconds	0.0667 foot	1/15,000
20.0 seconds	0.0970 foot	1/10,300
20.5 seconds	1.0000 foot	1/10,000
27.5 seconds	0.1333 foot	1/7,500
30.0 seconds	0.1454 foot	1/6,900
41.2 seconds	0.2000 foot	1/5,000
1 minute	0.2909 foot	1/3,400
3 min.-26.3 sec.	1.0000 foot	1/1,000

Note: The error for a given angle is equal to the "corresponding linear error."

Table of Contents

Chapter Four — Errors and Maximum Closures

Accuracy and Precision 4-1

Blunders and Errors 4-2

- Blunders 4-2
- Errors 4-3
  - Types of Errors 4-3
  - Sources of Error 4-4
  - How to Handle Errors 4-5

Compatibility with Previous Surveys 4-5

Maximum Allowable Errors 4-6

- Levels 4-6
  - Bench Levels 4-6
  - Bench Marks 4-6
  - Other Levels 4-6
- Traverses Closures 4-7
  - Control Traverses 4-7
  - Property Corner Tie Traverses (Secondary Traverses) 4-7
  - Radial (Side Shots) Ties to Property Corners 4-7
  - Bridge Surveys (Additional Right of Way Not Required) 4-7
  - Conventional Surveys 4-8

Chapter Four
Errors and Maximum Closures

Linear, angular, and vertical measurements are the basic operations performed by the surveyor. The application of mathematics (geometry and trigonometry) is used by the surveyor and engineer to convert field measurements to the horizontal and vertical relationships needed to produce maps or plans of engineering projects.

The surveyor must become adept at making the required measurements to the degree of accuracy required. The tolerances in the precision to which the measurements are made and the accuracies achieved by them must fit the needs for each type of survey.

The use of common sense and development of good surveying practice in all phases of a survey cannot be over-emphasized. No manual can cover all conditions that may be encountered on the actual field survey. The manual may specify certain techniques, such as a certain number of repeated operations, to achieve a required accuracy. The surveyor must often use judgment based on the equipment being used and the field conditions encountered, to modify those requirements. The stated requirements are considered the minimum. Some field conditions — heat waves or wind, for example — may make it impossible to perform some operations to a consistent degree of accuracy.

Accuracy and Precision

Accuracy is the degree of conformity with a standard or a measure of closeness to a true value. It is distinguished from precision, which relates to the quality of the operations used to obtain the result. The standard used to determine accuracy can be:

- An exact value, such as the sum of the three interior angles of a triangle is 180 degrees.
- A value of a conventional unit as defined by a physical representation, such as the international meter.
- The sum of the interior angles of a traverse is equal to (N - 2) times 180 degrees.
- A survey or map value determined by refined methods and deemed sufficiently near the ideal, or true value to be held constant for the control of dependent operations. USC&GS bench marks and triangulation points may be deemed of sufficient accuracy to be the control for other surveys; Montana's High Precision GPS network is another example.

Precision is the degree of refinement in the performance of an operation or in the statement of a result. The term "precise" is also applied to methods and equipment used in attaining results of a high order of accuracy, such as invar rods or precise tilting levels.

Generally, the accuracy of a field survey depends directly on the precision of the instrument. Although due to compensating errors, surveys with high-order closures might be attained without high-order precision, such closures are meaningless. Therefore, all measurements and results should be quoted in terms that are commensurate with the precision used to attain them. Similarly, all

surveys must be performed with a precision that ensures that the desired accuracy is attained. Surveys performed to a precision that excessively exceeds the requirements are costly and should be avoided.

Blunders and Errors

Field observations and the resulting measurement are never exact. Any observation contains various types of errors. Often some of these errors are known and can be eliminated by applying appropriate corrections. But even after all known errors are eliminated, a measurement will still be in error by some unknown value. Usually, the more precision used in making the observations, the less the magnitude of the unknown error. However, a measurement is never exact, regardless of the precision of the observations.

Although this manual contains many guidelines and standards, the ultimate responsibility for providing surveys that fulfill desired accuracies remains with the field personnel. To meet this responsibility, the field project manager and the party chief must understand errors, including:

- the various sources of errors,
- the effect of possible errors upon each observation, each measurement, and the entire survey, and
- economical procedures that will eliminate or minimize errors and result in surveys of the desired accuracies.

Blunders

A blunder, also called a mistake, is an unpredictable, human mistake. It is not an error, although a small blunder may remain undetected and have the same effect as an error. Examples of blunders are:

- transposing two numbers,
- neglecting to level an instrument,
- misplacing a decimal point,
- misunderstanding a callout,
- backsighting an incorrect turning point or control point, and
- not extending the level rod the full length for a high rod reading.

Blunders are caused by carelessness, misunderstanding, confusion or poor judgment. They are, for the most part, avoided by alertness, common sense, and good judgment.

Blunders must be detected and eliminated by using proper procedures, such as:

- making independent check observations and measurements,
- checking each recorded and calculated value,
- closing each survey, and
- recording slope distances to backsights when traversing or taking side shots.

Blunders must be eliminated prior to correcting and adjusting a survey for errors.

Errors

The error in an observation is the difference, after blunders have been eliminated, between a measured value of a quantity and the true value of that quantity.

Types of Errors

There are two general types of errors: systematic and random (accidental).

Systematic Errors. A systematic error is an error that always has the same magnitude and the same algebraic sign under the same conditions.

In most cases, systematic errors are caused by physical and natural conditions that vary in accordance with fixed mathematical or physical laws. However, some may result from the observer's tendency to react mentally and physically in the same way under similar conditions.

A systematic error of a single kind is cumulative. However, several kinds of systematic errors occurring in any one measurement could compensate for each other. Some examples of systematic errors are:

- incorrect switch setting to compensate for the prism offset,
- thermal contraction or expansion of a steel tape,
- incorrect ppm setting on an EDM or total station,
- curvature and refraction,
- tendency to sight in a slightly different manner on near sights than on far sights, and
- use of a level when the line of sight is not perpendicular to gravity.

Although some systematic errors are difficult to detect, the surveyor must recognize the conditions that cause such errors. Once the conditions are known, the effect of some systematic errors can be eliminated or minimized as follows:

- differential levels — balancing foresight and backsight distances,
- standardized tapes — making appropriate temperature corrections,
- measuring horizontal angles and zenith — direct and reverse, and
- automatic total stations — recording horizontal and vertical distance in direct and reverse modes.

When systematic errors cannot be eliminated by procedural changes, corrections must be applied to the measurements. These corrections are computed from the fixed relations between the systematic error and the conditions of the observations. A simple example would be the temperature correction applied to a taped measurement. All systematic errors must be eliminated prior to any adjustment of a survey. This generally is accomplished by using correct procedures and mathematically correcting the measured value.

Random Errors. A random error (or accidental error) is an error that does not follow any fixed relation to the conditions or circumstances of the observation. For a single measurement, it is the error remaining in the measurement after all possible systematic errors are eliminated.

Random errors are produced by irregular, complex causes that are beyond the control of the observer. Their occurrence, magnitude, and algebraic sign cannot be predicted. Each is truly random.

Random errors obey the laws of chance and are analyzed by the laws of probability. A complete discussion of the mathematical laws of probability is beyond the scope of this manual. The reference list in Appendix B includes some excellent publications that cover probability.

Theoretically, a random error has an equal chance of being negative or positive. Thus, errors of this type tend to be compensating. However, since the magnitude is also a matter of chance, random errors, to some degree, remain in every measurement.

Some examples of random errors are:

- The centering of an optical tribrach over a traverse point. The surveyor attempts to center the optical plummet exactly. In reality the tribrach may be left or right. This random error is referred to as centering error and is present whenever an optical tribrach or the traditional plumb bob is used.
- The reading of a level rod. The surveyor typically reads the rod to the nearest hundredth of a foot. The cross hair seldom is at an exact hundredth and, thus, the surveyor must make a decision.
- The reading and pointing of a theodolite. Surveyors are doing their best to align and read the instrument. In reality, the instrument may be pointing slightly left or right. The instrument operator makes random errors in reading the micrometer.

Mathematical corrections cannot be applied to random errors. The Department primarily uses the compass method for adjustment of traverses. Such adjustments are only what is believed to be the best approximation of the true coordinate values. Even after adjustment, each individual value, such as the coordinates of a specific point, are still in error by an unknown amount. In other words, balancing a traverse does not "fix" a poorly executed traverse that contains systematic errors, excessive random error or blunders.

Sources of Error

There are three general sources of errors: personal, instrument, and natural.

Personal Errors. Personal errors are caused by the physical limitations and observing habits of an observer. They can be either systematic or random.

Personal systematic errors are caused by an observer's tendency to react the same way under the same conditions. For example, a chainperson may measure slightly long on every measurement because he/she always stands in a certain position when taping. Each observer, whether he/she believes it or not, makes a personal systematic error of a small degree on each individual observation. Fortunately, such errors are minimized by proper procedures.

Personal random errors are caused by the physical limitations, sight and touch, for example, of an observer. As with systematic errors, such errors are always present, to some small degree, in every observation. Common sense and attention to proper procedures generally keep such errors to a minimum.

Instrument Errors. Instrument errors are caused by imperfections in the design, construction, and adjustment of instruments and other equipment. Some of these imperfections are:

- eccentricity of theodolite circles,
- misadjustment in the calibration of EDMs, and
- misadjustment of plate levels.

Most instrument errors are eliminated by using proper procedures, such as observing angles direct and reverse, balancing foresights and backsights, and repeating measurements. Instrument errors that are not eliminated by procedures must be minimized by maintaining a regular program of periodically checking and adjusting (or calibrating) instruments and other equipment.

Natural Errors. Natural errors result from natural physical conditions such as atmospheric pressure, temperature, humidity, gravity, wind, and atmospheric refraction.

Natural errors are removed from a measurement by determining corresponding corrections from known relationships between an error and the related natural phenomena. The ppm correction for temperature and pressure is a familiar example. The natural effect of curvature and refraction can be eliminated in leveling by balancing foresights and backsights, or in a traverse, by using reciprocal zenith angles.

How to Handle Errors

All surveying measurements are subject to systematic and random errors. Systematic errors need to be eliminated using proper procedure, or corrections must be applied to the measured values. It is preferable to eliminate systematic errors by using correct procedures. Examples of proper procedures are:

- adjust tribrach plummet;
- traverses — measure all angles using both a direct and a reverse reading;
- correct PPM settings on EDMs; and
- level circuits — keep backsight and foresight distances approximately equal.

After systematic errors are eliminated, random errors need to be addressed. Random errors occur during the course of any survey. They cannot be eliminated; nor can corrections be applied. An example is the readings associated with an optical theodolite.

The compass adjustment is based on the theory that no systematic errors are present, and random errors tend to accumulate based on distances from the point of beginning. Traverse adjustment (balancing) is not a valid method for distributing systematic errors or blunders.

A level circuit may not close exactly. Is the misclosure due to a systematic error, random error, blunder, or a combination of the three? The misclosure cannot be adjusted if it is due to a systematic error or blunder.

Compatibility with Previous Surveys

Most new surveys will either generally follow old surveys or make ties to old surveys. Because the methods and equipment (transit and steel chain) were far less precise than current methods and equipment, the original stations will not be in agreement with the new measured or computed centerline stations.

It must be assumed, therefore, that new centerline stationing, either measured directly or computed from traverse points, is based on the most accurate information, and the new stationing should take precedence over the old stationing.

The project coordinate system provides a common base by which old and new surveys may be related. All monumentation of the existing facility should be tied to the new survey and properly identified. Generally, when original distances, such as record right of way, must be computed, they

may be computed on a proportionate basis, providing the original monumentation has been adjusted. Otherwise, the found monumentation will control.

Maximum Allowable Errors

As mentioned earlier in this chapter, systematic errors must be eliminated by calculations or by correct procedures. They cannot be corrected by distribution of the error. Blunders (mistakes) must be eliminated. Random errors must be held to a minimum.

Levels

Bench Levels

Bench levels are the primary vertical control throughout the length of a project and, generally, are the first levels on a project. They should be of the highest accuracy. The vertical error in levels may be due to systematic errors, random errors or mistakes. Since systematic errors and mistakes must be eliminated, the error of closure should be due only to random errors. Random errors in levels are functions of distances or the number of turning points between the two established bench marks.

The maximum permissible closure in bench levels is:

$$3 \times 0.005\text{-feet} \times \sqrt{\text{Number of Foresights}}$$

For example, if your bench level had 12 foresights, the maximum error is 0.052 foot, rounded to the nearest 0.01 foot. If the actual error is greater than 0.05 foot, the level loop contains systematic errors, excessive random errors or mistakes. The levels must be rerun.

If the error of closure is less than or equal to the expected error, this error is then distributed. Adjust the elevations of all bench marks, horizontal control points and aerial photography control points within the loop. The adjustment is proportionate based on the number of foresights in the loop. Turning points do not need to be adjusted.

Bench Marks

All new bench marks on all projects will consist of a 5/8-inch x 30-inch rebar.

Other Levels

This category of levels consists of:

- differential levels from known bench marks or traverse control points to aerial photography control points (500 and 600 numbers);
- differential levels from known bench marks or traverse control points to new bench marks, new traverse control points, or additional control points not used during the initial bench levels; and
- trigonometric levels to aerial photography control points from known traverse control points or bench marks.

The survey crew should strive to adhere to the maximum permissible closure given above. Use of good leveling procedures should result in meeting this requirement. However, it is recognized that in certain situations, this maximum closure will not be met. In these situations, time spent rerunning loops is not warranted. Therefore, the absolute maximum closures are:

- 0.10 foot for differential or trigonometric levels to aerial photography control points from traverse control points or bench marks; and

- 0.05 foot for differential levels from known control points or bench marks to unknown control points or bench marks.

Traverses Closures

Control Traverses

The control traverse serves as the primary horizontal control throughout the length of a project. It typically is the first traverse conducted and should be of the highest accuracy. As with bench levels, systematic error and mistakes cannot be corrected by balancing a traverse. The errors must be eliminated before balancing. The errors in a traverse must be the result of random errors only.

Angular Error. The maximum permissible angular error in a control traverse is:

$$\text{7 seconds} \times \sqrt{\text{Number of Setups}}$$

This product is rounded up to the nearest whole second. For example, if your control traverse loop has 15 setups, the maximum angular error is 27.1 seconds, rounded to 28 seconds.

Closure After Angular Adjustment. The minimum traverse closure, after satisfying the angular condition, is 1:45,000, but the linear error (closing distance) in no case can exceed 0.60 foot.

Property Corner Tie Traverses (Secondary Traverses)

This traverse is used to tie property controlling corners, property corners and aerial photography control points to the control traverse.

Angular Error. The maximum angular permissible error in the property control traverse is:

$$\text{10 seconds} \times \sqrt{\text{Number of Setups}}$$

This product is rounded up to the nearest whole second. For example, if a traverse has five setups, maximum angular error is 22.4 seconds, rounded up to 23 seconds.

Closure After Angular Adjustment. The maximum linear error, after satisfying the angular condition, is:

$$\text{0.10 foot} \times \sqrt{\text{Total Distance}/1000}$$

In no case will the linear error be greater than 0.50 foot.

Radial (Side Shots) Ties to Property Corners

This type of survey can be used to tie property controlling corners, property corners and aerial photography control points to the control traverse. It is used instead of a traverse.

The radial error is the distance between the two sets of coordinates of the monument tied. These coordinates usually are obtained from two control points, from a P.O.L., or from one control point using different backsights. The radial error in all cases must be less than or equal to 0.25 foot.

Bridge Surveys (Additional Right of Way Not Required)

This type of survey is used on bridge reconstruction or rehabilitation projects. It usually is a conventional type survey, although some bridge projects may be mapped using aerial photography. The maximum possible errors are different for conventional surveys and aerial mapping.

If a conventional (centerline traverse) survey is used, and all topographic features are tied to the centerline, the linear error in the centerline traverse, after satisfying the angular condition (see

Property Corner Traverse requirements above), must be less than or equal to 0.50 foot. The maximum vertical closure error is the same as that for bench marks and other levels. These surveys are not balanced. The centerline traverse is held, but the traverse is computed to verify that the linear error is less than 0.50 foot. Ties to property controlling corners and property corners are not necessary since additional right of way is not required.

Photogrammetric bridge surveys, or bridge surveys where additional right of way is needed, require a control traverse. The specifications for control traverses, levels and property corner ties are as stated above.

Conventional Surveys

Conventional surveys are used only on projects that do not require additional right of way. Conventional surveys, other than a conventional survey associated with a bridge project, typically are open traverses (reserved for overlay projects only). Thus, no minimum errors can be specified for this type of survey.

Table of Contents

Chapter Five — Preliminary Surveys

Preliminary Field Review Report 5-1

Control Surveys 5-1

- Planning and Research 5-2
- Reconnaissance 5-4
- Establishment and Numbering of Control Points 5-4
- Abstract 5-6
- Bench Levels 5-7
  - Maximum Vertical Error and Adjustment 5-7
  - Government Bench Marks Are Present 5-7
  - Government Bench Marks Are Not Present 5-8
  - Limited Number of Government Bench Marks 5-8
- Control Traverses 5-8
  - Definitions 5-8
  - Instruments and Number of Positions Required for Control Traverses 5-10
  - Instruments Not Used for Control Traverses 5-11
  - Basis of Bearing and Origin of Coordinates 5-11
  - Horizontal Angular Measurements 5-11
  - Distance Measurement and Reduction to Horizontal 5-11
  - Angular Closure 5-12
  - Traverse Balance/Adjustment 5-12
- Baseline 5-13
  - Establishment of Angle Points on the Baseline 5-13
  - Cross Sections and Profile 5-15
  - Topographic Features 5-15

Aerial Photography 5-17

- General 5-17
- Ground Control 5-17
- Aerial Survey Procedures 5-18
- Target Locations 5-18
- Horizontal Control Points 5-21
- Vertical Control Points 5-21
- Check Cross Sections 5-24
- Map Editing 5-24

Conventional Surveys 5-26

Bridge Surveys 5-26
Aerial Photography Utilized or Additional Right of Way Required 5-26
Aerial Photography Not Utilized and Additional Right of Way Not Required 5-27
Additional Surveys 5-28
Preliminary Survey Requirements 5-28
Project Manager's Recommendations 5-28
Submitting the Survey 5-28

Figures

5-1 Reference for a Control Point 5-3
5-2 Typical Horizontal Control 5-5
5-3 Atypical Horizontal Control 5-6
5-4 Traverse Loop Connections 5-9
5-5 Establishment of Angle Points on the Baseline 5-14
5-6 Target Placement from an Obstruction 5-19
5-7 Best Times for Mapping Photos 5-20
5-8 Target Dimensions 5-22
5-9 Vertical Control for Mapping 5-23
5-10 Check Cross-Section Locations 5-24
5-11 Tie an Existing Conventional Survey to Newly Established Control Traverse 5-26
5-12 Preliminary Survey Requirements 5-29

Chapter Five
Preliminary Surveys

This chapter deals with preliminary surveys and their requirements. Examples of preliminary surveys are:

- control surveys,
- aerial photogrammetry surveys,
- conventional surveys,
- bridge rehabilitation and reconstruction projects,
- ties to property corners, property controlling corners, and right-of-way monumentation (refer to Chapter Six), and
- hydraulic surveys, which are covered in Chapter Ten.

The purpose of a preliminary survey is to gather all information that is required by Photogrammetry, Design, Bridge, Hydraulics, and Right of Way. This chapter discusses the procedures and steps to be followed for the different types of surveys that may be requested. Appendix A contains sample field notes for these surveys.

Preliminary Field Review Report

A Preliminary Field Review Report is developed for each project. This report addresses such items as the project location and limits, existing physical characteristics of the bridge or the roadway, traffic characteristics, scope of work, and major design features. Included in this report is the type of survey required. It is important that the survey requested be complete and appropriate.

Control Surveys

The control traverse is used exclusively for all projects that require, or may require, additional right of way, and on all projects that utilize aerial photography. The control survey will replace the conventional survey on many projects. The conventional survey consists of staking centerline every 50 or 100 feet.

Examples of projects utilizing the control survey are:

- aerial photography projects,
- new construction projects,
- reconstruction projects, and
- bridge projects where aerial photogrammetry is used or additional right of way is required.

Conventional surveys are restricted to overlay and other projects that will not require additional right of way. If the scope of the project is changed to reconstruction, the control traverse will be used and the conventional survey will be tied to the control traverse. The conventional survey is then adjusted to fit the control survey. The Preliminary Field Review Report should be developed with this in mind.

The purpose of any control survey is to establish a permanent, recoverable horizontal and vertical control network. Topographic features, controlling property corners, property corners, aerial photography control points, right-of-way references, right-of-way monuments, apparent centerline, and the baseline are tied to the control survey. The control survey is used to lay out the designed centerline and right of way.

A control point that is in danger of being destroyed should be referenced. Refer to Figure 5-1 for approved methods and Appendix A for sample field notes. The note format is based on the instrument used. Manual total stations require slope distances and a set of zenith angles.

Automatic total stations require two horizontal distances: one direct and one reverse. The distances from the two readings must agree within 0.02 foot. A control point reset from references will be monumented with an approved 2-inch aluminum cap. The cap will be stamped: "RESET," the original point number, and the current year. Do not use a control cap.

A separate field book is to be used for all references and resetting of control points. This work typically is done during construction. It is the party chief's responsibility to see that all required referencing is accomplished. If new control points are necessary, they are to be set using the control traverse procedures. When numbering the new control points, do not duplicate any existing or destroyed control point numbers. The coordinates are to be determined using the method covered later in this chapter.

Preliminary surveys generally follow the sequence covered below.

Planning and Research

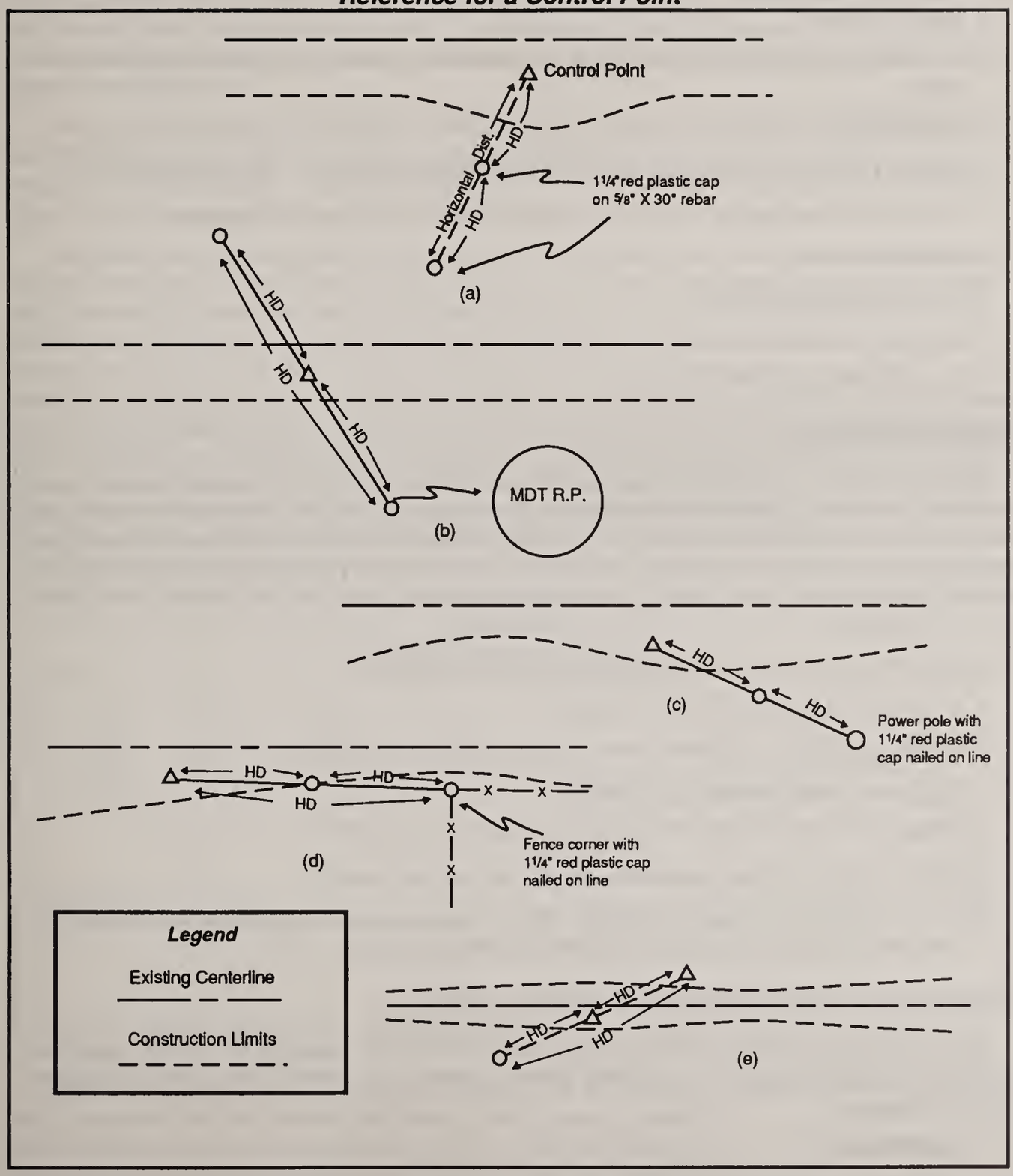
Planning, research, and reconnaissance are not unique to the control survey. They should be part of all preliminary surveys. These topics are covered as part of the control traverse.

Planning ensures that the necessary information is gathered. The District Engineer is responsible for notifying landowners of the proposed project. This may be delegated to the District Construction Engineer, the District Engineering Services Supervisor, the Field Project Manager, or others. Permission to enter private property must be obtained prior to the entry. The field project manager and party chief should be made aware of any special requests or conditions reported on the right of entry form.

Vital information should be obtained by searching the available land records. The records are kept at the county courthouse, usually in the office of the Clerk and Recorder. However, actual interviews with the landowner or the landowner's agent are sometimes necessary. Information from this research is useful in the determination of written ownerships, location of existing property corners along the proposed project, and boundaries that may be affected by the proposed construction. The research may include, but is not limited to:

- county maps;
- as built plans;
- existing right-of-way plans and monumentation;
- USGS quadrangle maps;

Figure 5-1
Reference for a Control Point



- previous department information in the area;
- utility locations;
- recorded maps and plats (subdivision plats, certificates of survey, and deed exhibits are examples);
- railroad plats;
- General Land Office (GLO) and Bureau of Land Management (BLM) plats and field notes;
- locations and descriptions of existing NGS, USC&GS, USGS, etc., bench marks;
- applicable deeds;
- existing aerial photography;
- existing horizontal control; and
- the preliminary field review report.

Reconnaissance

The field project manager should seek as much assistance as is required to get the control survey off on the right track. If there are any questions, the field project manager should ask his/her supervisor at this time. The Photogrammetry and Survey Section is available for assistance as well. One important aspect of the reconnaissance is to determine what existing horizontal and vertical control is available, its suitability for the survey, and whether additional control will be required. Some questions to be asked are:

- How was the existing control established and to what accuracy?
- Is the existing control in the best location?
- Will it suit all the survey needs for this project through construction?
- Will a new control traverse be required?
- Where are the best locations for the control traverse monuments?
- Where is the new project centerline probably going to be located?
- Where might the construction limits be? This is important since it is the responsibility of the field project manager that control monuments are not destroyed.

Establishment and Numbering of Control Points

The District will determine whether a new control traverse is necessary or whether additional control points are to be added to an existing control traverse. New control points should be located taking into account:

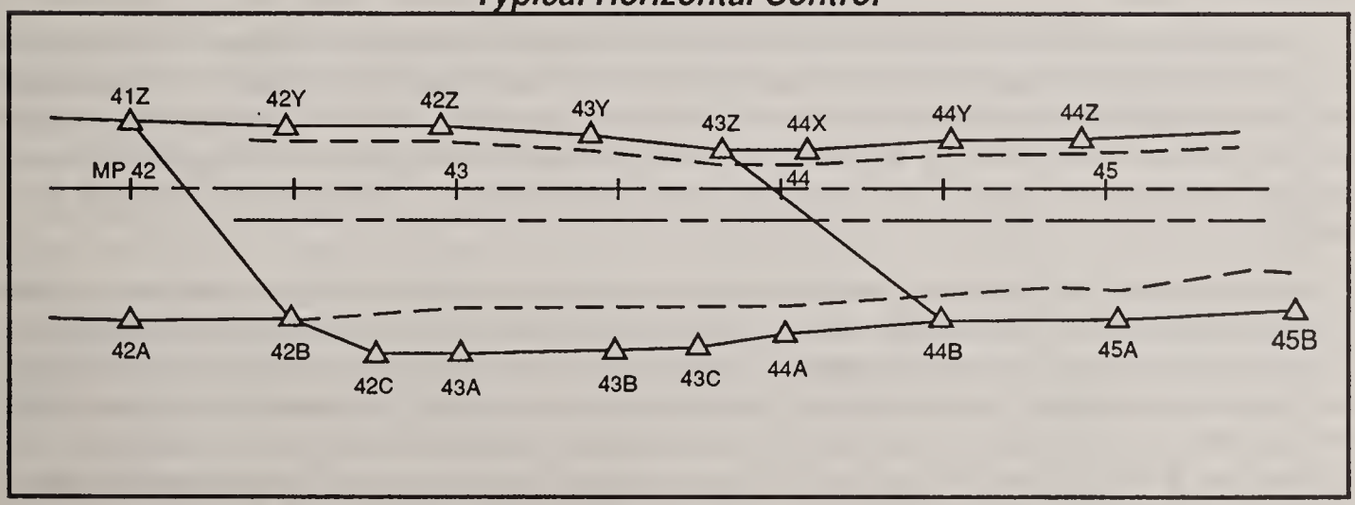
- accessibility,
- estimated construction limits,
- maximum and minimum distances allowed for control traverses,
- safety of the field crew, and
- the chances the existing monument will not be disturbed or destroyed during the construction of the project.

The preliminary field review report may provide information as to the expected location of the designed centerline. The ideal scheme will have monuments located at intervals of one-half mile, on the average, along both sides of a project. This facilitates the ties to topographic features, existing monumentation, and photo control points, and layout of the designed centerline and associated right-of-way monumentation.

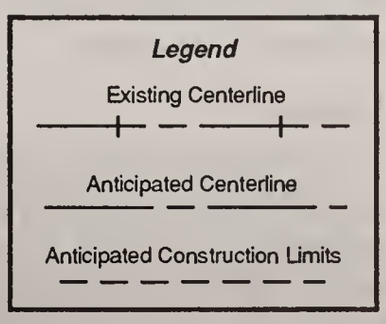
Control traverse points are generally located along each side of the proposed project. There may be cases when it is advisable to locate the traverse completely on one side of the proposed project — along a river, for example, where there is no room on one side. The newly established or existing control points must provide for visibility ahead and back.

The numbering of the control points is based on mile posts. The identification number used in the field notes, and stamped on the monument, is the route mile post number to the nearest whole mile followed by a letter designation. The letter designation is the next available letter (A, B, C, etc.) for the forward traverse, and the next descending letter (Z, Y, X, etc.) for the return portion of the traverse. For example, the first control point on the forward traverse between mile post 43 and 44 would be assigned the number 43A, the second 43B, etc. On the return portion of the control traverse the first control point between mile post 43 and 44 would be assigned the number 43Z, the second 43Y, etc. Do not use the letters I, O or Q. They can be confused with numbers. The field notes should show the letter Z with a horizontal line drawn through the middle to distinguish it from the number 2. Figure 5-2 shows a typical traverse numbering sequence for one traverse loop. This is the preferred configuration.

Figure 5-2
Typical Horizontal Control

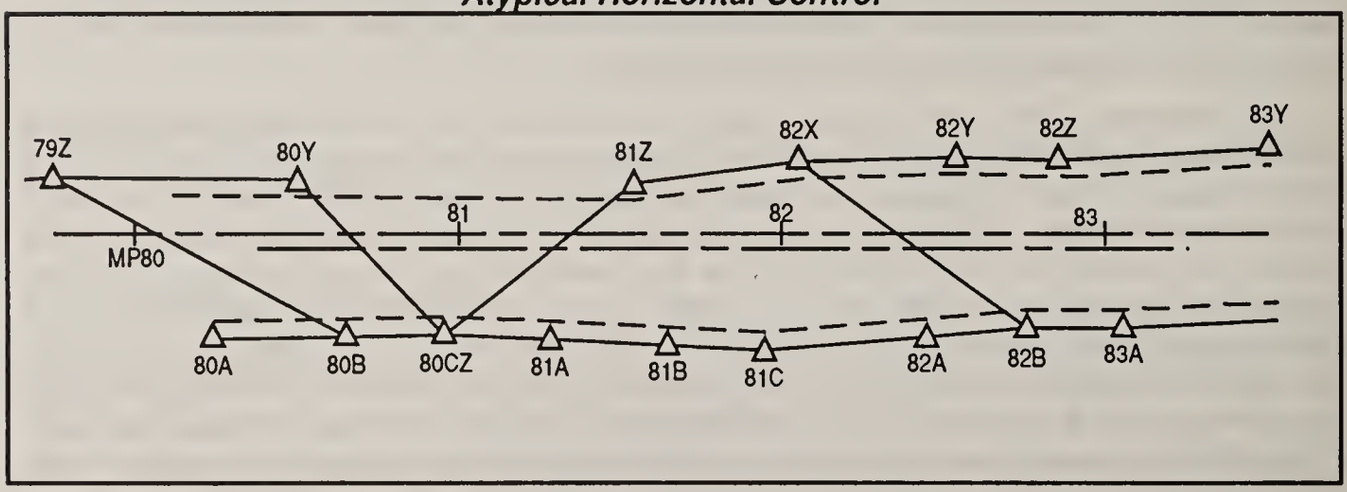


There are situations when the preferred method may not be advisable. Examples would be limited sight distance due to terrain, property owners not wanting field crews on their land, excessive vegetation on one side of the road as opposed to the other side, etc. In these cases the alternate scheme can be used. The forward and backward traverse may occupy nearly the same location on the ground. When these points are going to be very close together (less than 10 feet), there is a potential for error in identifying or occupying the wrong point. One single point eliminates this problem. Figure 5-3 shows the common point 80CZ. The cap is stamped 80CZ. The point is identified in the field notes and the abstract as 80C and 80Z.



Traverse computations are carried through the point as if it were two separate points. The compass or Crandall adjustment will give different coordinates of 80C and 80Z. The final abstract will list the coordinates of 80C and 80Z. A least squares adjustment will list the coordinates of 80CZ. Again, the numbering sequence shown in Figure 5-2 is preferred, rather than that shown in Figure 5-3.

Figure 5-3
Atypical Horizontal Control



If a new route alignment is planned and there are no existing mileposts, approximate mileposts can be scaled on a USGS quadrangle map and used instead of mileposts. Vehicle odometers may be used as well.

Accuracy in mile post location is not important, but duplication of point numbers is. This must not occur. Do not duplicate any control point numbers. If a traverse point is destroyed, do not reuse the number. Destroyed points should be noted, but their coordinate values are maintained so that computations are easily made for anything tied to the destroyed point. Prior to working on the project, the field project manager should request a current abstract of the existing control points on the project.

Sites selected for control are monumented at this time. All control traverse points are to be exclusively identified. The standard control monument is a 5/8-inch x 30-inch rebar with an approved 2-inch aluminum cap. This cap is prestamped with the Department's name and a triangle. The aluminum cap is to be stamped with the control point number and the year. A galvanized steel post with the Department's decal attached will be driven as close to the monument as practical. It should not be so close that it will interfere with setting the instrument over the monument. Other monuments, such as brass caps, can be used if the existing monuments can be exclusively identified. In this case do ***not*** stamp the existing monument with the control point number or year. All new control points should be flush with the ground.

Abstract

The abstract of control points is started at the time the control point is set. Separate pages of the field book are to be reserved for the descriptions. The field project manager or the party chief has the responsibility to see that the description of the monument, at the time it is set, is suitable. The location description must include the mile post location (to the nearest 0.1 mile), the distance left or right of centerline, and the location of the witness post and decal. The description of the monument must include the size and type of cap, the size of the rebar, whether the monument was found or set, and how the monument was stamped. Additional location description should be included, if appropriate.

A hand compass is very useful and should be used to determine directions to features such as fence corners. Most distances can be paced. Refer to the sample notes given in Appendix A. The northing (Y coordinate), easting (X coordinate), and if determined the elevation (Z coordinate) will be added to the abstract after the traverse has been computed. The final abstract will include all the information in this and the preceding paragraph. The abstract should be on a computer disk (3.5 inches) as a text file. The abstract is sent to the Photogrammetry and Survey Section with the rest of the control survey data.

Bench Levels

The purpose of bench levels is to establish conveniently spaced, permanent points of known elevations throughout the length of a project. Whenever possible, existing United States Coast and Geodetic Survey (USC&GS), United States Geological Survey (USGS) or National Geodetic Survey (NGS) bench marks are to be utilized. Bench levels are generally the first levels on a project. The datum used must be cited in the field notes, for example: NGVD29, NAVD88, or assumed.

Different conditions may exist: USC&GS, NGS, or USGS bench marks are present throughout the project at regularly spaced intervals, they are not present along the project, or there are one or two for the entire length of a ten-mile project. The method used for bench levels will be determined by the presence or lack of these federal bench marks.

Bench levels can commence at the same time the control monuments are being established if the crew consists of three or more persons. The crew chief can set the control traverse monuments, stamp the monuments, set the witness post and write the description. Other crew members can commence the bench levels.

The elevations determined at this time will serve as the primary vertical control. Elevations of all control points may not be necessary. If differential leveling to a control point will be time consuming, and there is no practical value in having the elevation of that control point, the elevation is not required. The notes should indicate the reason the elevation was not determined. The abstract should have a line drawn in the elevation column and not left blank.

All control traverse points, additional benches, and angle points on the baseline must have levels turned through them using differential levels. Intermediate foresights to these points are not permitted. The elevations of the horizontal control points used by Photogrammetry (600 series) and the vertical points (500 series) can be determined using differential or trigonometric levels. Intermediate foresights are not permitted if differential levels are used. Differential levels are preferred. Trigonometric levels were discussed in Chapter Three. Additional information can be found in Chapter Six.

Maximum Vertical Error and Adjustment

The maximum errors allowable for levels and how to adjust the level circuits are discussed in Chapter Four.

Government Bench Marks Are Present

Bench levels should commence at a found, identifiable bench mark and be run to the next found, identifiable bench mark. All convenient control points should have bench levels run through them at this time. The elevations of the missed control points are determined, at a later time, using the adjusted elevations of the known control points. The control traverse points may be used as bench marks and will replace the need for having separate bench marks at approximately every 1000 feet. The traditional bench mark can still be established. The elevation of the government bench marks

will be, in most cases, considered fixed. Return circuits are not necessary if you check into an existing bench mark within the tolerances given in Chapter Four.

Government Bench Marks Are Not Present

If a found, identifiable bench mark is within two miles of any point of the project, the bench mark will be used. The elevation is brought into the project site using differential levels. This newly established bench mark will then be used to establish all other elevations associated with the project. If a government bench mark is not within two miles of the project, the elevations of survey points on the project will be determined using previous highway bench marks, city bench marks, or other approved bench marks.

Bench levels should consist of loops no more than 3000 feet in each direction. Elevations of all convenient horizontal control points should be determined at this time. The forward run should include control points, additional benches, and photo control points near centerline. The return should consist of only turning points. The elevations of missed control points on the forward run are determined using the adjusted elevations of the control points, additional benches, or photo control points. Do not use turning points.

Limited Number of Government Bench Marks

It is impossible to discuss all the various combinations that can exist. General guidelines are: use all that are present, and adjust errors as explained in Chapter Four.

Control Traverses

The control traverse serves as the primary horizontal control throughout the length of a project. The EDM must be checked against a baseline prior to running the control traverse. Refer to Chapter Three. The control traverse, in most cases, replaces the conventional survey. All information tied to a centerline traverse will be tied to the control traverse. This facilitates more efficient use of automatic and manual total stations.

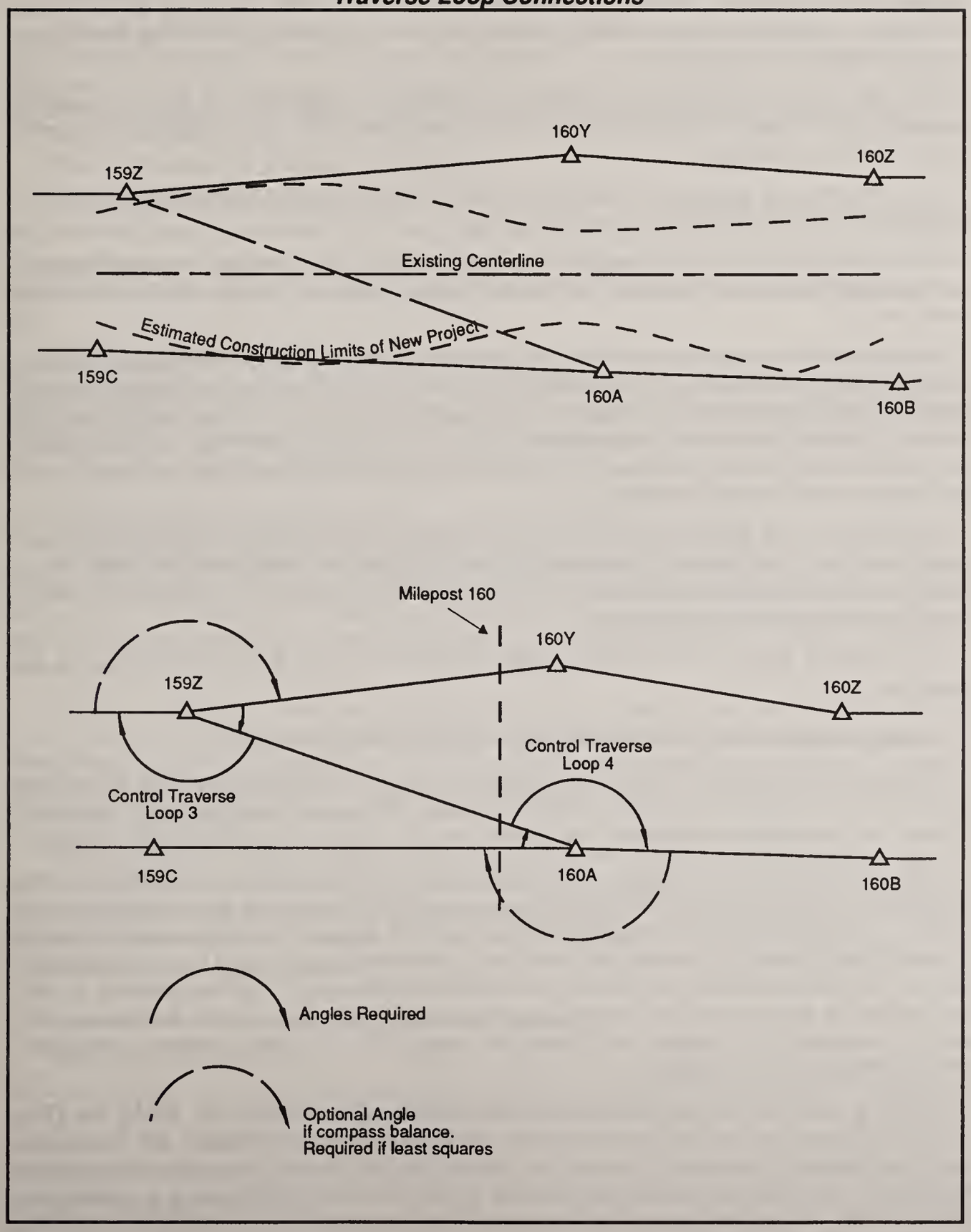
Traverses are run in loops approximately 2.5 miles long (5 miles total), but in no case will the loop contain more than 20 points. Terrain limitations may require the length of the traverse to be shortened.

Each loop is adjusted, before adjustment of the next loop, unless the least squares method is used. Each successive loop must have two points in common with the previous loop. These points are held. Refer to Figure 5-4. If the traverses are being computed using the compass or Crandall method, the coordinates of 160A and 159Z are computed using the data associated with Loop 3. These coordinates are now held. Traverse 4 is now adjusted. The beginning coordinates are the coordinates previously computed for point 160A. The ending coordinates of Loop 4 are the coordinates previously computed for point 159Z. Angular error must be distributed prior to using the compass or Crandall adjustment. These adjustments require the angles shown in Figure 5-4 at control points 159Z and 160A. The least squares adjustment requires the optional angle shown at control points 159Z and 160A.

Definitions

Closed Traverse. A traverse that begins at a known position and closes back to the same point, or that closes on a different known point. The preferred closed traverse begins at one known point and closes on a different known point.

Figure 5-4
Traverse Loop Connections



Control Traverse. The main scheme closed traverses that are performed to the highest degree of precision used on a project. The control traverse is used as the horizontal datum base for all aspects of a project. Secondary traverses or ties to property corners, and property controlling corners, are made from the control traverse.

HI. The height of the instrument is the vertical distance measured from the top of the control monument to the center of the horizontal axis of the instrument. This point is marked by a punch mark or dot on the instrument.

HS. The height of the signal is most often a prism. It is the vertical distance measured from the top of the control monument to the center of the prism.

Open Traverse. A traverse that begins at one point and ends at another point, where the horizontal relationship between the beginning and ending points is unknown. Control traverses are never open traverses.

Position. For the measurement of horizontal angles, a position is the act of making direct and reverse pointing on each survey point to which a direction is required. A complete position consists of two direct and two reverse pointings to each object observed. More than one position may be required, depending on the survey requirements. A position is the term used when horizontal angles are measured using the directional method. The horizontal circle remains stationary for a given position, but is reset for each new position.

Set of Angles. For the measurement of horizontal angles, a set of angles is a series of horizontal angles where each observation is accumulated on the horizontal circle of the instrument. Half the set is measured in the direct mode and half in the reverse mode. This term is used when measuring horizontal angles using the repeating method.

Set of Zenith Angles. A set of zenith angles consists of a direct and reverse pointing of the instrument.

Instruments and Number of Positions Required for Control Traverses

Instruments are classified by the least division that can be read directly from the micrometer drum or by their stated DIN (Deutsche Industrie-Normen). They are not classified by the least division that can be estimated or displayed. The repetition method is ***not*** to be used on control traverses.

One- to three-second (least count or DIN) instruments, such as the Wild T-2, Lietz TM-1A, Lietz Set II, Set III, T1600, or equivalents, require four positions. Circle settings are approximately, but not exactly, equal to 00 degrees, 45 degrees, 90 degrees and 135 degrees. The initial setting can be an exception. The difference in the angle measured direct and reverse must be equal to or less than eight seconds. Any meaned position greater than five seconds from the mean of the four positions, or that has a difference greater than eight seconds, must be returned. Only that position that was rejected needs to be returned. If a position was rejected, the mean of the four good positions is computed. Refer to sample notes in Appendix A.

The four- to six-second (least count or DIN) instruments, such as the Lietz 3F, Wild T-1A, ITS-1B, ELTA 5, or equivalents, require five positions. Circle settings are approximately, but not exactly, equal to 00 degrees, 36 degrees, 72 degrees, 108 degrees, and 144 degrees. The initial setting can be an exception. The difference in the angle measured direct and reverse must be equal to or less than fifteen seconds. Any position greater than ten seconds from the mean of the five positions, or that has a difference greater than fifteen seconds, must be returned. Only that position that was rejected needs to be returned. If a position was rejected and returned, the mean is recomputed. Refer to sample notes in Appendix A.

Instruments Not Used for Control Traverses

Instruments having a least count or DIN value greater than six seconds will not be used for control traverses. Examples are Wild-T1, Lietz T60D, Lietz 3E, transits, CTS-1, A20A or equivalents. Instruments having a least count or DIN less than or equal to 10 seconds may be used for property corner ties, cross sections from the baseline, layout, referencing, conventional surveys, and the like.

Basis of Bearing and Origin of Coordinates

All surveys must have a beginning bearing. This bearing can be obtained from a solar observation, existing centerline, existing right-of way, GLO, BLM, or a Certificate of Survey. A solar observation is the preferred method. Appendix A shows the notes for one set of observations. A complete observation consists of three sets. The solar observation should be taken near the middle of the project.

Coordinates are assumed for projects not having fixed control. The assumed coordinates should be large enough that negative coordinates do not occur. Projects must have only one basis of bearing and one coordinate system. All sections working on this project will use the same orientation and coordinate system developed by the District or the Photogrammetry and Survey Section. The origin of bearings and coordinates should be stated in the field notes.

Horizontal Angular Measurements

All angles will be measured to the right from the backsight. All backsights and foresights will be a target and prism secured in a tribrach fastened to a tripod. The extension of a prism using a pole is not permitted. All tribrachs will have optical plummets. The optical plummets are to be adjusted prior to commencing the control traverse. This should be done at the time of the baseline measurement.

The correct number of positions are turned, the angles are meaned, and any positions that are rejected are returned prior to moving the instrument. It is important that the instrument remain level throughout the series of measurements. This is the instrument operator's responsibility. If the total station is out of level, the instrument should be releveled and centered over the control point. Do ***not*** continue to measure angles.

When the required angular measurements are satisfied, the instrument is released from the tribrach (the tripod and tribrach are not moved) and replaced by a prism. The foresight prism is released and the instrument is placed in that tribrach. The backsight, tripod and prism are moved to the new foresight. The traverse is from tribrach to tribrach. The instrument and prisms are leapfrogged. The tripods and tribrachs remain stationary.

Distance Measurement and Reduction to Horizontal

At each traverse point the distance will be measured to the backsight and the foresight. It is important that the correct ppm and prism offset be set in the instrument. The Department typically uses Lietz prisms and targets. The prism should be mounted using the -30 mm offset and not the 0 mm offset. The EDM must have the same offset as the prism, -30 mm. The notes should show the temperature, pressure, and ppm set in the instrument. The information recorded depends on the type of instrument and how the reduction to horizontal will be made. Three methods exist for this reduction:

- slope distance and the difference in elevation of the instrument and the prism,
- slope distance and a set of zenith angles, or

- automatic total stations (Set 2 and 3) can be set to display the horizontal distance. Curvature and refraction should be toggled on.

The first method requires the HI and HS to be recorded in all cases. The ground elevation of the control points must be known. Zenith angles are not required.

The second method does not require HIs, HSs, or elevations of the control points. The slope distance and a set of zenith angles must be recorded. Do not reduce the slope distance to the horizontal and record the horizontal distance only. The slope distance and the zenith angles must be shown in the field notes. The sum of the direct and reverse zenith angles must show consistency. It is the notekeeper's responsibility to verify consistency and inform the instrument operator if additional zenith angles are required.

The third method is used only if an automatic total station is available. The horizontal distance may be recorded, provided the distance is recorded in the direct and reverse pointings to the backsight as well as the foresight. The direct and reverse horizontal distances at a control point must agree within 0.02 foot. If this tolerance cannot be achieved, one of the other two methods must be used. This method does not require recording HIs, HSs, slope distances, or zenith angles. (The Lietz 3E and 3F are ***not*** classified as automatic total stations; therefore this method cannot be used with these instruments.)

The maximum length of any leg in the control traverse is 3,000 feet. The minimum should not be less than 1,000 feet. In situations where the terrain limits sight distances to less than 1,000 feet, the crew should take additional precautions to keep the centering error in the tribrachs to a minimum.

Angular Closure

The angular closure that exists within a closed traverse must be due to random errors only. Systematic errors and blunders need to be eliminated prior to the adjustment of the angular error in a traverse.

The angular error is a function of the number of traverse points, horizontal distances to the backsights and foresights, atmospheric conditions, care in centering the tribrachs, precision of the instrument being used, stability of the instrument, and abilities of the observer. Angular error greater than the expected error cannot be adjusted. The angular error must be located in the field. Chapter Four gives the maximum angular error that is allowable.

Angular error may be distributed using any of the following methods:

- Adjust all angles by equal amounts;
- Adjust the horizontal angles associated with the shorter distances more than the angles associated with longer distances; or
- Adjust using the least squares method.

The first method is the most common and in most cases the preferred method, provided a least squares adjustment is not used. The second method requires some common sense and should not be used on a trial-and-error approach solely to reduce the linear error in a traverse.

Traverse Balance/Adjustment

Approved methods of traverse balancing/adjustment are:

- compass,
- Crandall, or

- least squares.

The preferred method to distribute random errors is the least squares adjustment. The compass and Crandall methods can be used. These two methods require the angular error to be adjusted prior to balancing of the traverse. The least squares adjustment requires no adjustment of the angular error. The adjusted angles are determined in the adjustment. All traverses, after the angular error has been distributed, must close within the maximum errors stated in Chapter Four. If not, do not balance the traverse. The traverse must be remeasured or the error must be located in the calculations or the field work. An excessive linear error is an indication that systematic errors, excessive random errors, and/or a blunder are present.

Districts should send all traverse control data, including the computations, the abstract (on disk), and differential levels to the Photogrammetry and Survey Section for final checking. The Photogrammetry and Survey Section may decide to use a least squares adjustment. It is important that the final checking be done prior to distribution of the field data to other sections or bureaus.

Surveys using State Plane Coordinates do not require any coordinate computations by the Districts. The Districts will continue to determine the angular error in these traverses. This angular error must be less than the maximum errors given in Chapter Four. All computations will be done in Helena.

Baseline

The baseline replaces the centerline traverse on projects using a control survey. The baseline serves as the "G" line. It is not necessary to reestablish the existing centerline. The baseline consists of a series of angle points that are tied to the control traverse. The baseline does not contain any curves.

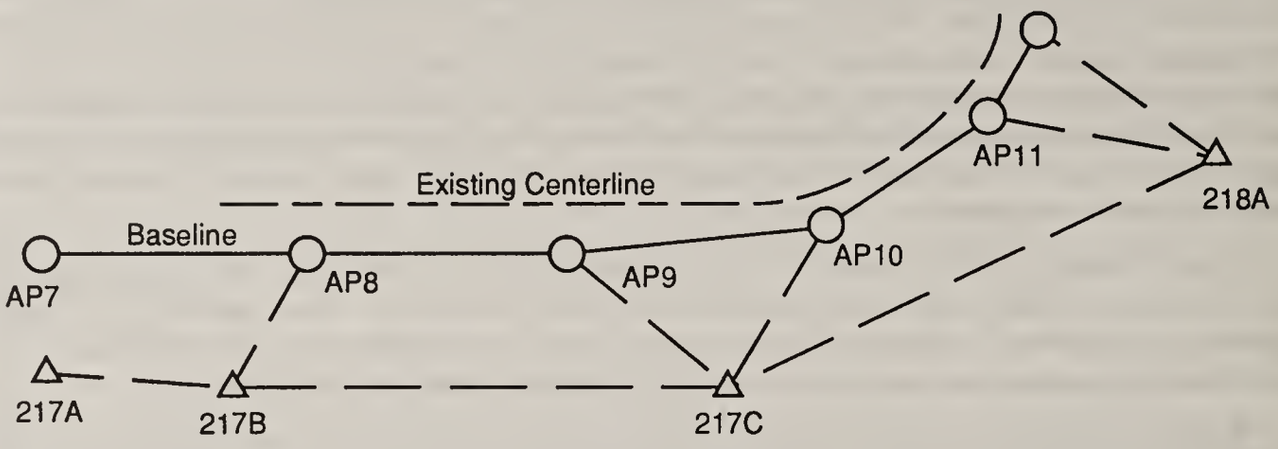
Establishment of Angle Points on the Baseline

The angle points are tied from the control traverse using one position for the horizontal angle and one set of zenith angles. The maximum difference between the angle measured direct and the angle measured reverse must be less than twenty seconds. Refer to Figure 5-5(a) and Appendix A for sample notes. The measurements to the angle points should be made in conjunction with the control traverse. This eliminates the need to occupy the control traverse points for the sole purpose of setting the angle points. The slope distance is recorded along with a set of zenith angles. When an automatic total station is used, the horizontal distance direct and reverse are recorded, but the direct and reverse horizontal distance must be within 0.02 foot. Zenith angles and the slope distance are not required in this case.

The angle points are to be 5/8-inch rebar with a 2-inch aluminum cap. The control traverse cap is ***not*** to be used. The cap is stamped AP 1, AP 2, AP 3, etc., and the date. The cap should be set flush with the ground. The angle points are the only points permanently monumented on the baseline. POTs may be hubs and tacks, punched railroad spikes, and the like.

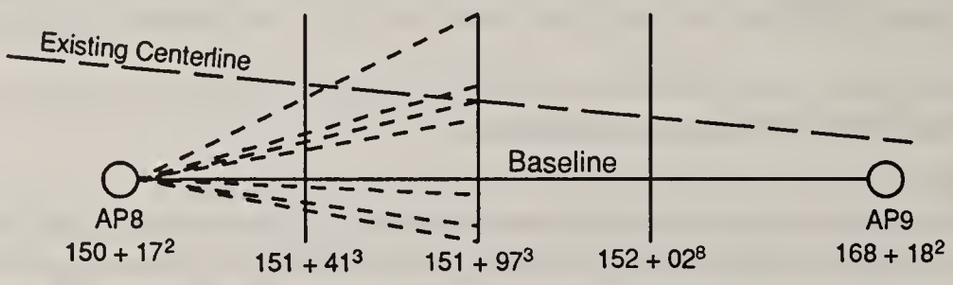
The elevations of the angle points are determined using differential levels. The first angle point should be located at least 500 feet before the beginning of the project. The last angle point should be located at least 500 feet past the end of the project. The maximum distance between angle points is 2,000 feet. The maximum distance to a cross section from an angle point is 1,000 feet. The angle points should be located away from the pavement and traffic. Sharp curves in the existing alignment may require more frequent angle points.

Figure 5-5
Establishment of Angle Points on the Baseline

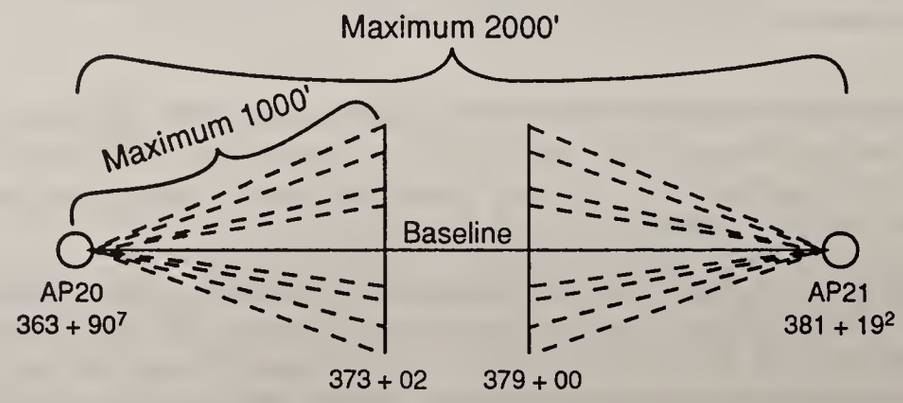


(a)

Cross Sections from the baseline



(b)



(c)

The first angle point is generally assigned the station number 0+00. Station numbers of the remaining angle points are determined by cumulative inversed distances. Equations will not occur.

Cross Sections and Profile

The distance and elevation of the foresight angle point must be verified prior to obtaining any cross sections on the tangent. The cross sections and profile of the baseline are obtained at the same time using a manual or automatic total station. The elevations are determined using the zenith angle. A set of zenith angles is not required. Instruments having an index error should be adjusted, or a correction should be applied to the direct reading.

The Preliminary Field Review Report or instructions from the District will give the cross section interval required. This interval is obtained by pacing along the baseline. Cross sections do not need to be taken at even stations. The HP-41 program "Station and Offset" is required. A copy of this program and the documentation maybe obtained from Helena. The elevation, HI, and HS are entered as prompted by the program. The sight pole and prism are placed on line. The horizontal angle, slope, distance, and zenith angle are entered as prompted by the program. The program gives the notekeeper the station number, the offset distance (the offset distance on the baseline should be 0), and the elevation of the ground at the prism. After all information is obtained on this cross section, the process is repeated at the required interval until the angle point ahead is reached or the distance to the cross section exceeds 1,000 feet. This process is then repeated for the length of the project. Refer to Figure 5-5(b) and (c) and the sample notes in Appendix A. It is necessary that the field crew fully understand this procedure prior to cross sectioning.

All profile information, cross sections, and topography are obtained with the instrument at the angle points. Topography can be tied from the control traverse as well. The general procedure for taking cross sections is:

- Sight the prism on the angle point ahead with the horizontal circle reading zero degrees.
- Measure the horizontal distance and compare it to the distance used for stationing of the baseline. This distance should be within a foot of the stationed distance. Hold the stationed distance.
- Measure the zenith angle (direct only) and the slope distance. Compute the elevation of the AP ahead. This elevation should be within 0.2 foot of the elevation obtained from differential levels. Hold the differential elevation. The HS can be equal to the HI.
- Set a foresight on the angle point ahead. This sight is used periodically as the cross sections are obtained. It provides a check of the circle setting.
- Obtain cross sections. A sight pole and prism are used.

Topographic Features

Topography is defined as all physical objects or features, whether man-made or natural, in or adjacent to the highway corridor that would normally be shown on the plan sheets. The survey includes such items as existing fencing, roads, buildings, power lines, land features, waterways, railroads, pipes, and utilities. Because the plans are developed solely from field notes, follow these minimum requirements for location and identification of topographic features:

- Include in the notes fence type, post spacing, location of existing gates, and the condition of the fence.

- Identify pole lines by location of the centers of the poles. Include the type of line, number of wires, pole number and owner's name.
- Show all buildings with dimensions, types of construction, addresses, and owners, if known.
- Note the type of land use.
- Show irrigation ditches and canals, streams, etc.
- Show all utilities.

Topography can be further divided into two categories: above ground and below ground. Above-ground topography includes man-made or natural objects and features.

The location of underground utilities requires office research, field investigation, and contacts with utility companies. The locations and depths shown on existing plans may not be exact, and should be verified in the field. Unless otherwise requested, the survey should include all utilities within 200 feet of the proposed centerline in rural areas and 10 feet behind the proposed construction limits or curbs in urban areas.

Pipelines. As a minimum the following should be included:

- centerline crossings by station or coordinates 150 feet each side of the proposed centerline;
- depths to top of pipe at points near the anticipated right of way lines;
- locations of vents;
- locations of bends; and
- locations of meter vaults and valve pits.

Water and Sewer Lines. As a minimum the following should be included:

- centerline crossing by station or coordinates 150 feet each side of the proposed centerline;
- locations of manholes, valve boxes, meter pits, crosses, tees, and bends;
- elevations of tops of lines, sewer invert elevations, manhole ring elevations, and elevations of tops of manholes; and
- locations of fire hydrants and curb stops.

Power Lines. As a minimum the following should be included:

- locations of supporting structures on each side of the proposed centerline;
- locations of poles on parallel lines that may require relocation, locations of overhead guys, stubs and anchors; and
- in cases of buried power, locations of cables, pull boxes, voltage, transformer pads, as well as notes about whether the lines are buried directly or are in conduit.

Telephone Lines. As a minimum the following should be included:

- locations of poles that may require relocation, locations of overhead guys, stubs and anchors;
- in cases of buried telephone cables, denote whether the lines are buried or in conduit, the locations, the number of conduits, and if fiber optic cable, the number of pairs; and
- locations of pedestal boxes.

Topographic features may be located from the baseline. Topography may also be located from the control traverse. Manual total stations will locate all topography using a single horizontal angle (direct only), a single zenith angle (direct only), and a slope distance unless elevations are required. If elevations are required, the HS and HI must be recorded and the zenith angles must be corrected for index error. Automatic total stations can locate topography using a single horizontal angle and the horizontal distance. If elevations are required, the HS, HI, and vertical distance must be recorded. Curvature and refraction switch settings must be shown in the field notes.

Aerial Photography

General

Photogrammetry uses aerial photography to measure features on the earth's surface. The Department's policy is to use photogrammetry wherever possible. There are many advantages and some disadvantage of photogrammetry. Some advantages are:

- It provides a permanent record of conditions that existed at the time of the aerial photographs.
- It can provide a large mapped area so alternative line studies can be made on paper.
- It provides an overall view of the project area, identifying both topographic and cultural features.
- The photographs can be used to convey or describe information to the public, state and federal agencies, and other divisions within the Department.
- It can be used in locations that are difficult or impossible to access.
- It requires less field work.
- Cross sections can be extended easily.

Some disadvantages of aerial photogrammetry are:

- Weather conditions affect the taking of aerial photographs.
- Snow cover can obliterate the targets or give false ground elevations and/or ground relief.
- Ground cover, such as dense timber or other vegetation, may limit the use of photogrammetry.
- The accuracies of the mapping depends on the flight height and the accuracy of the field survey. The mapping is dependent upon the coordinates and elevations supplied by the District.

The computed traverse, ties to horizontal control points, bench levels, abstract, and field notes are to be sent to Photogrammetry and Survey for review and processing. Missing or incorrect information will be referred back to the District.

Ground Control

Aerial photos are the basic tool used in photogrammetry mapping. Accurate field surveys are essential if an accurate mapping is desired. Each photo control survey has its own guidelines that reflect the requirements of the topographic map to be produced. These guidelines are given in the request for the survey. A written request for the survey is sent to the appropriate district. This request includes aerial photos and the general layout of the required photo control points.

The control survey procedures associated with aerial photogrammetry are identical to the methods discussed earlier in this chapter. Photogrammetry control points may either be a part of the control traverse, or be tied to the control traverse. Ties to aerial targets that are not part of the control

traverse are discussed in Chapter Six. The high order of accuracy of control traverse is necessary to produce accurate maps.

Aerial Survey Procedures

After authorization, a general aerial survey procedure is followed. It may be necessary to revise some of the steps. The Photogrammetry and Survey Section will instruct, and assist if needed, in all steps of the survey. Additional information requested by Preconstruction, Hydraulics, Bridge, or other areas of the Department should be routed through the Photogrammetry and Survey Section.

The preferred sequence for aerial surveys is:

1. The Photogrammetry and Survey Section will design the flight lines and determine the locations of the horizontal (600 numbers) and the vertical (500 numbers) control points.
2. Planning and research.
3. Reconnaissance.
4. Setting, stamping, and describing the control traverse points.
5. Setting, stamping, and describing the photo control points.
6. Bench levels.
7. Running of the control traverse.
8. Ties to photo control points that are not part of the control traverse.
9. Additional surveys.
10. Adjustment of the control traverse and ties to photo control points.
11. Random cross sections.
12. Map editing.

Several items above are covered in this manual under the heading "Control Surveys." They will not be covered here.

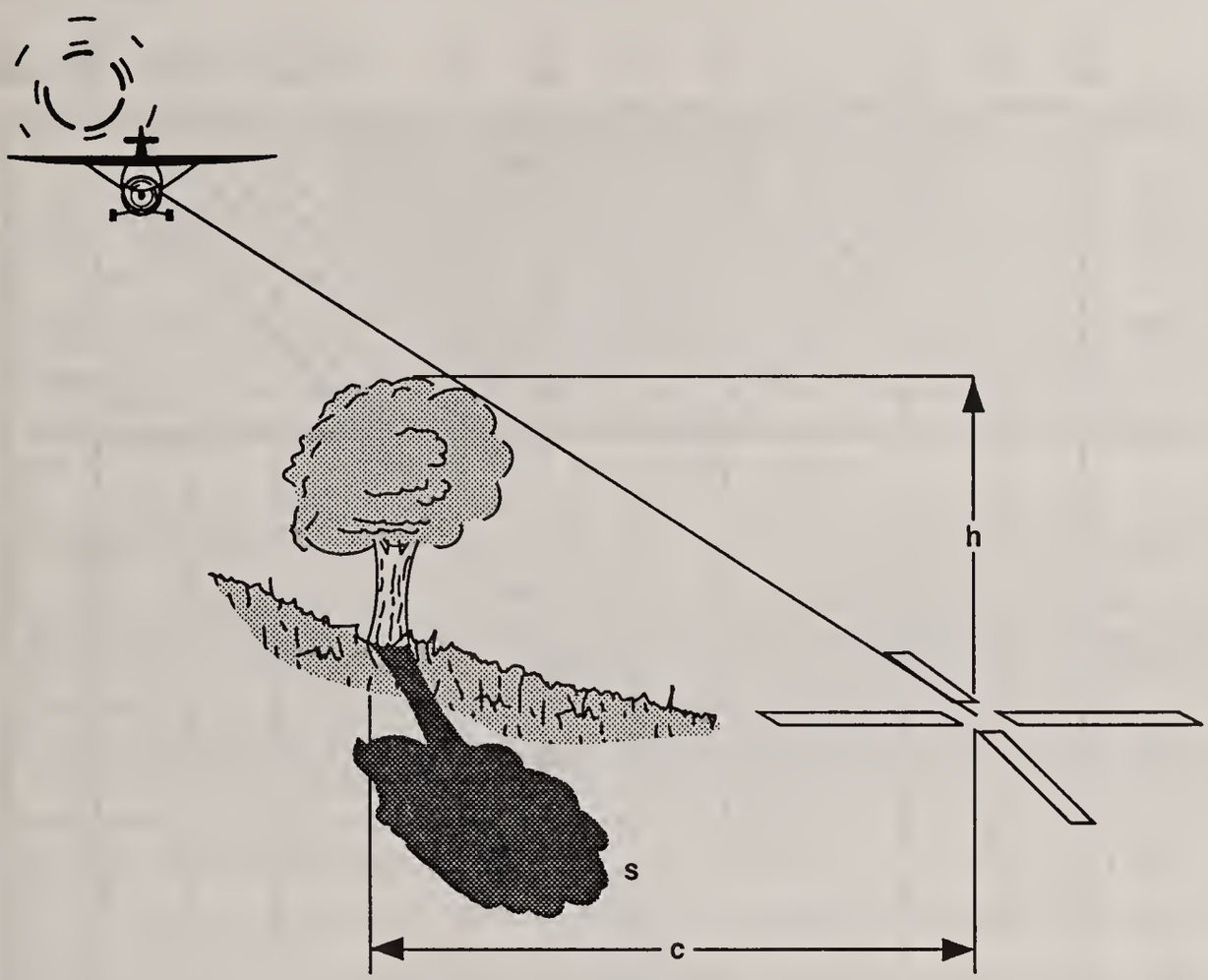
Target Locations

Targets should be located close to the positions indicated by the Photogrammetry Survey Section. Targets must not be located in shadows or in positions that will not be visible on the photograph. Figure 5-6 shows a general scheme for the determination of distances. The crosshatched areas in Figure 5-7 show the time of year and day when the sun is in the best position for aerial photography.

Targets should be located away from trees. Sagebrush and tall grass must be cleared away so the target is visible and is not obscured by shadows. Areas of tall grass and ground cover will give a false ground reading. The best spot for a target is on bare, flat ground away from obstacles.

Targets must be carefully centered over the control points. A target can be moved from its shown location but never more than 300 feet. It should be placed as close to the planned position as possible. Do not move targets closer to the project centerline.

Figure 5-6
Target Placement from an Obstruction

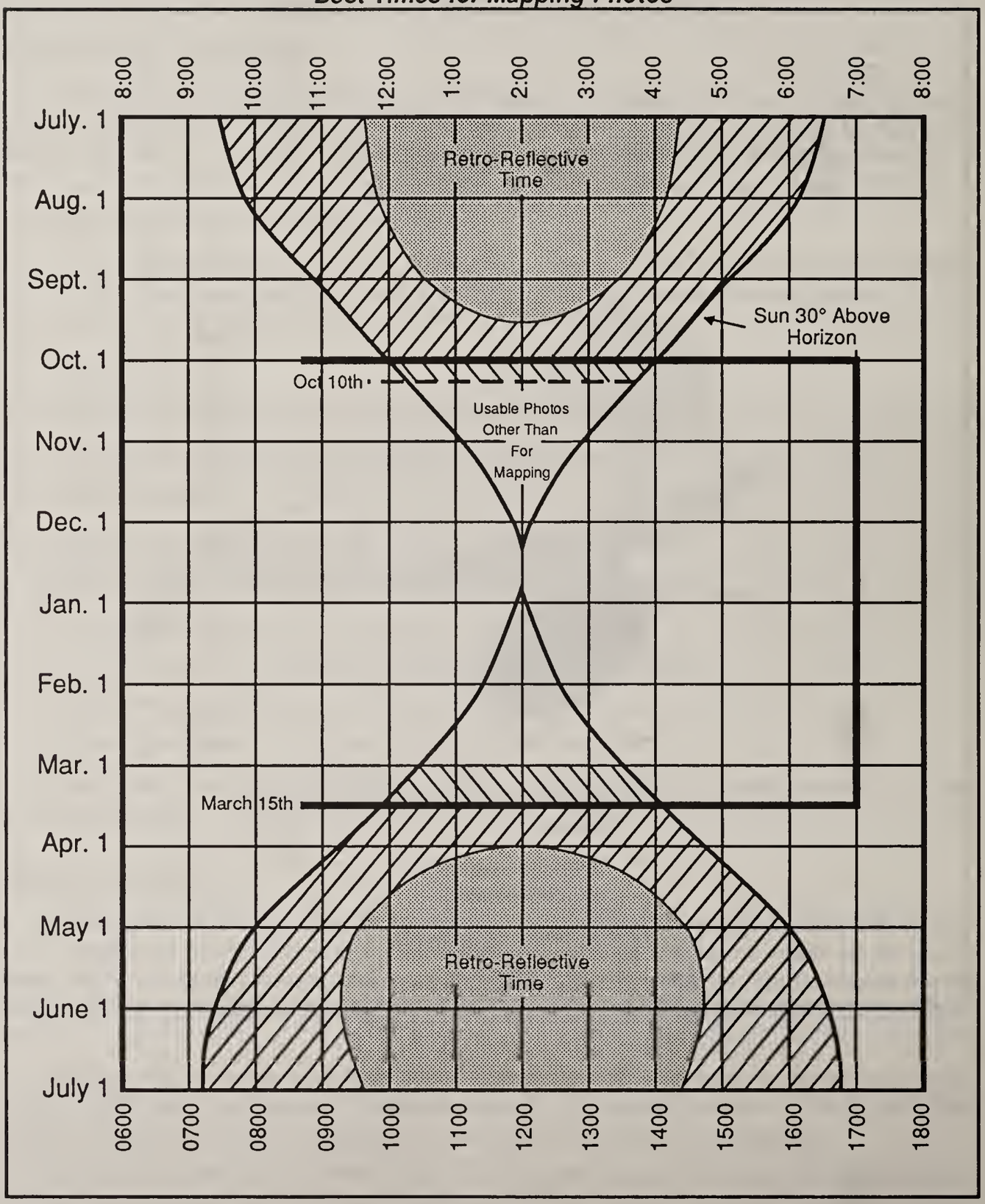


h = height of top of object above level datum target
c = clearance

c = 0.75h minimum
c = 1.0h desirable

s =- Area obscured by shadow

Figure 5-7
Best Times for Mapping Photos



Bare ground, dirt roads, or gravel roads may appear white on photographs. White targets may blend in. Figure 5-8 shows typical target size and an alternative target that may be used on light ground and roads.

Horizontal Control Points

Photographs supplied to the districts are premarked indicating locations of the targets. Red triangles are generally used to indicate the horizontal points. These points are the 600 series numbers. They are to be monumented using a 5/8-inch rebar and an approved 2-inch aluminum cap. The cap is to be stamped with the target number and the year. The cap should be flush with the ground. Target centers located on asphalt are marked by a PK or concrete nail. All 600 points require a northing, easting, and elevation. The elevation of the cap and the vertical distance from the cap to the ground must be shown in the field information and the abstract. In all cases this information must be given, even if the cap is flush with the ground. The abstract must list the mile post and distance left or right to the target, the type of monument, and the three dimensional coordinates of all the horizontal control points.

Vertical Control Points

The supplied photographs indicate location of the vertical control points using a blue circle. These are the 500 series numbers. The vertical control points do not require Y or X coordinates, a rebar and cap, PK nail or a target. They do require elevations and descriptions. The elevation shown in the notes must be the ground elevation. The survey crew should pick an appropriate point in the general location indicated on the photographs. The point selected must be identifiable on the photograph. It must be described in the field notes. These points should never be described using distances from visible points such as fence corners, power poles, etc. Below are some general rules for the locations of the vertical control points:

- Provide a sketch, complete with north arrow and ground features, showing the exact point that the elevation is given.
- Do not use the top of a rock or the top of a small feature.
- Use flat areas with readily identifiable features and preferably with little ground cover.
- Locate vertical control points midway between gate posts, on the centerline of a roadway perpendicular from a utility pole, at bases of utility poles, at fence corners, midway between bushes, at the base of a bush (if it is photo identifiable), at the end of a no-passing stripe on a road, on a manhole, or on the centerline of the highway opposite an approach road.
- Refer to Figure 5-9 for additional locations and sample sketches that should be included in the field notes.

Remember, if you cannot positively identify the point on your photographs, do not use it. Mark by a pinhole on the photograph the exact point. Draw a circle around the pin hole. Return the photos to Photogrammetry and Survey.

Some projects may not utilize aerial targets but will be controlled by photo identification. These projects still require 500 and 600 series points. The 600 series points should be located no farther than 1 foot from the photo identification point. These should be such objects as fence corners, power poles, or other identifiable points. The 600 series points should be marked with a flagged nail or hub and tack set flush with the ground. A rebar and cap is required. The field notes should indicate what was set. Mark the exact point on the photograph with a pinhole and circle the pinhole. Provide a complete sketch of all photo identification points.

Figure 5-8
Target Dimensions

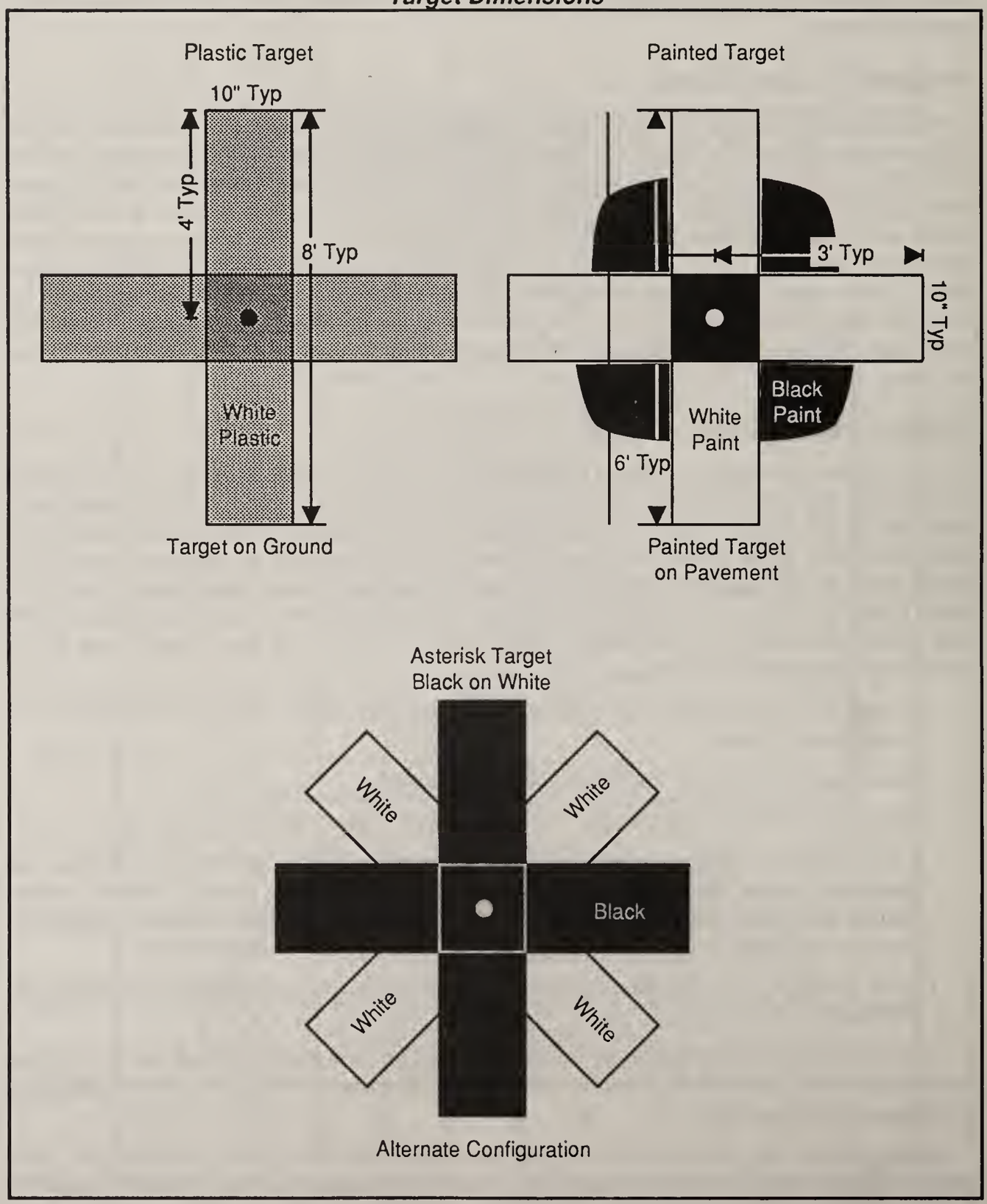
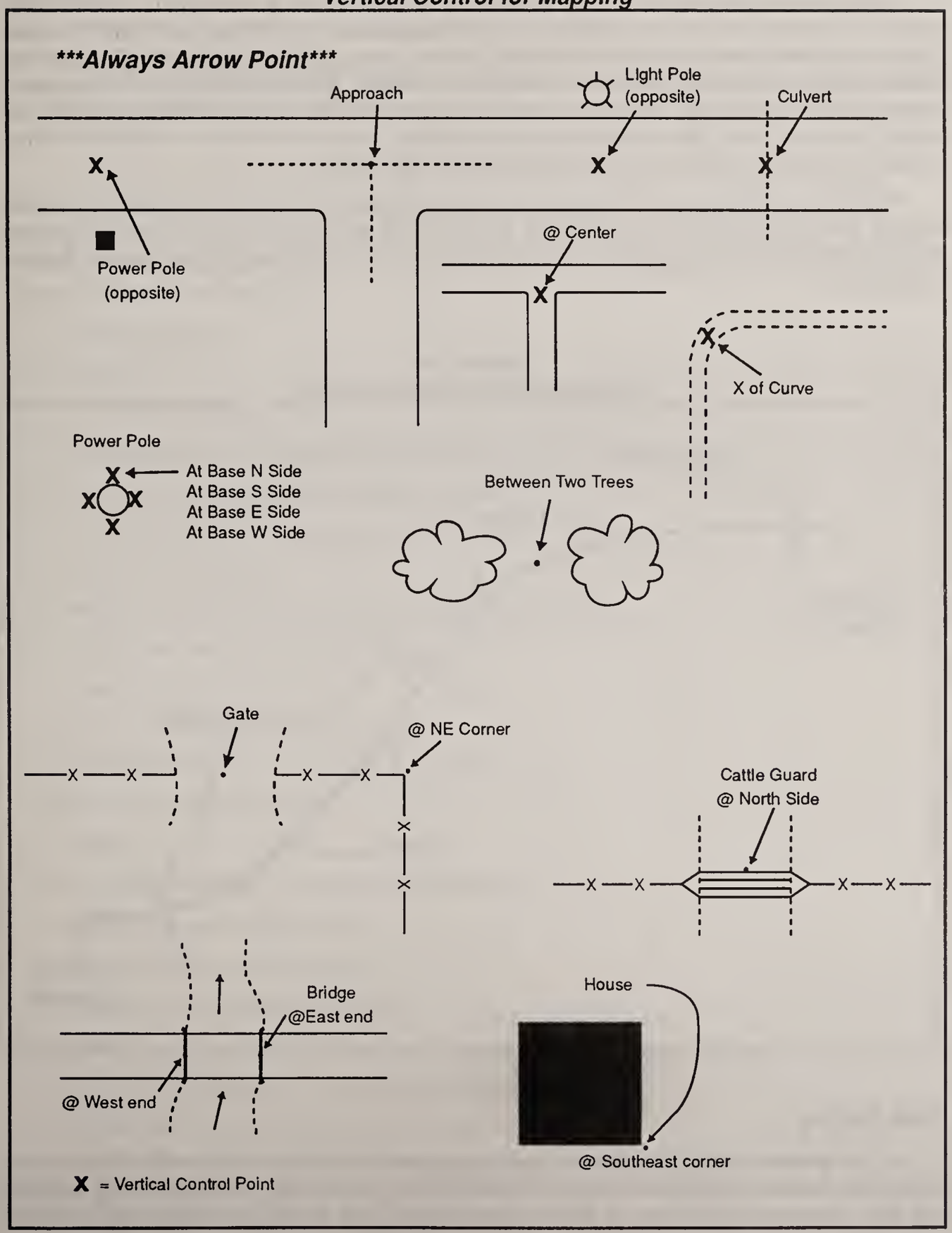


Figure 5-9
Vertical Control for Mapping

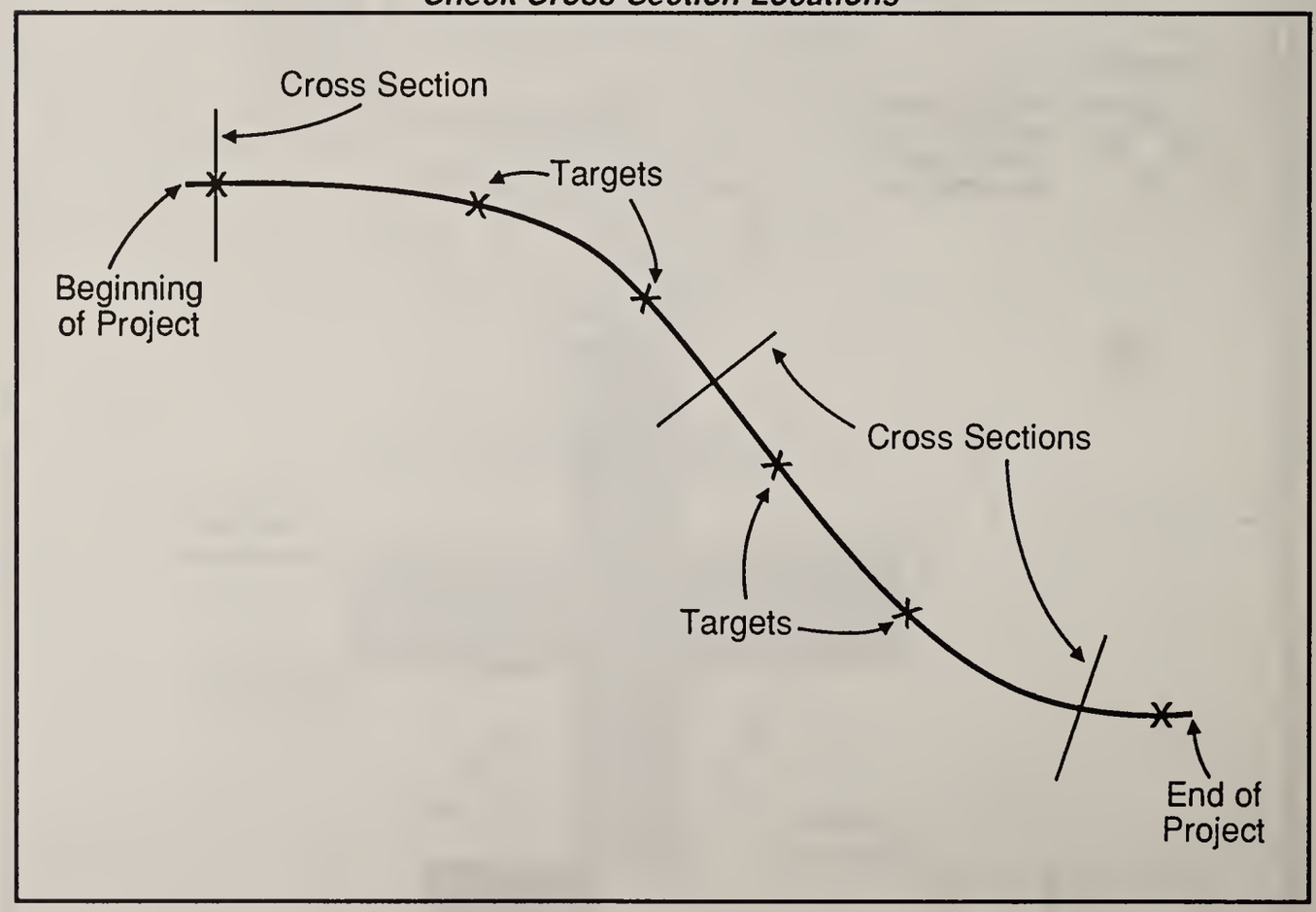


Check Cross Sections

The purpose of the cross sections is to verify the accuracy of the aerial mapping. A check cross section is a profiled line 300 feet or more that crosses the present traveled way at or near 90 degrees. The cross sections must have coordinates based on the control traverse at each end. The centerline station number of the cross section is not sufficient or needed. Stationing along the cross section is needed. Assume the station number at one end to be 0+00. The station number at the other end should be about 3+00. The maximum distance between stations on the cross section is 50 feet. Record the station and elevation of each shot along the cross section.

Three check cross sections are required: one near each end of the project and one near the middle. Include a targeted point on one of the cross sections. Take the other two cross sections at random locations between targeted locations to test the validity of the analytical bridging process. Refer to Figure 5-10.

Figure 5-10
Check Cross-Section Locations



Map Editing

A photogrammetric map is considered preliminary until its validity is field checked. Map editing consists of visually checking the topographic features shown on the map. It should correctly represent the field conditions. Such items as the locations of signs, mail boxes, power poles and lines, guy wires, fences and underground utilities need to be verified. The map editing needs to be done with the map in hand.

Corrections or additions to the map can be shown or plotted directly on the map. They can be located by coordinates or located by measurements from features that show on the map. Examples of editing are:

- Connecting power lines between power poles.
- Noting the type of fence on the map.
- Drawing guy anchors so they can be plotted. Orient them correctly and show distances from the poles.
- Locating a missing feature by giving distance from two features that appear on the map.

The final editing of the map must be done after all underground topography has been plotted. The final edited map should be signed and dated by the responsible party and returned to the Photogrammetry and Survey Section. All items that may affect the design should be shown. This may include, but not limited to, the following:

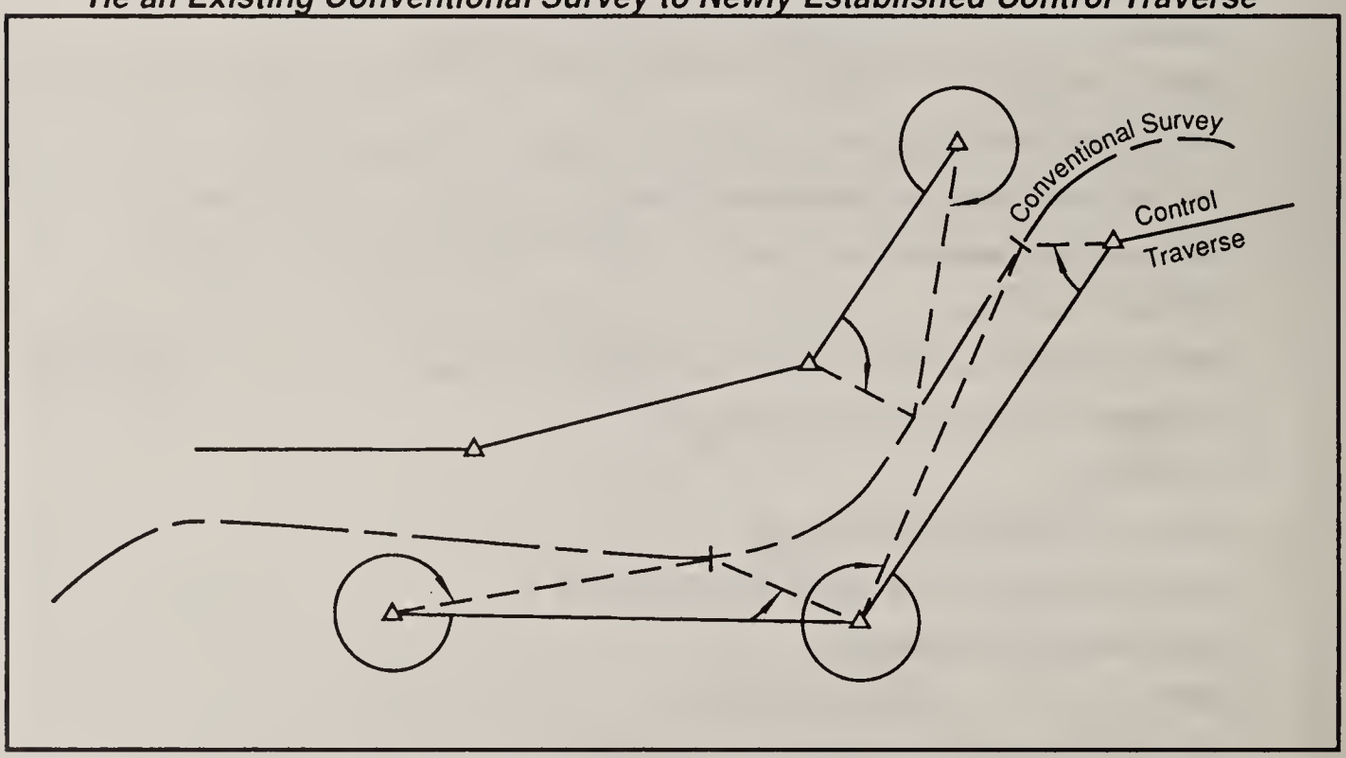
- buried pipelines,
- gas lines,
- buried power lines,
- buried phone lines and location of phone utility boxes,
- overhead power lines (and the number of lines),
- television cables (overhead and buried),
- wells and water lines,
- sanitary and storm sewers (include invert elevations and size),
- storm sewer inlets (with invert elevations),
- water valves,
- gas and water hook-ups to buildings,
- any utilities that are in the right of way or that cross it,
- septic tanks and drainfields,
- fences,
- culverts (include type, size, and invert elevations),
- irrigation ditches and structures,
- street traffic lights, and conduits,
- signals (include type) and conduits,
- graves,
- possible wetlands (identified by cattails and ponds),
- underground tanks and filler caps (abandoned or in use), and
- anything pertinent to the project that should be on the permanent plans.

Conventional Surveys

The conventional survey is restricted to projects that do not require additional right of way or aerial photography. An overlay is an example of a project that would use the conventional survey. The conventional survey consists of the reestablishment of centerline. The conventional survey will not set iron pins or rebar to reference the conventional survey. These monuments may be confused with references to the existing right of way. References for the conventional survey will be hubs and tacks. Profile elevations are taken along the centerline. The centerline is then cross sectioned. Topography is tied to the centerline traverse.

If the scope of the project changes and aerial photography or right of way is required, a control survey is necessary. The conventional survey is tied to the control traverse, and the conventional survey is adjusted to fit the control survey. A weighted least squares adjustment will be used, if at all possible. The conventional survey now becomes in effect a baseline. Refer to Figure 5-11.

Figure 5-11
Tie an Existing Conventional Survey to Newly Established Control Traverse



Bridge Surveys

Preliminary surveys are necessary for both bridge rehabilitation and reconstruction projects. These projects may be "on system" or "off system." The projects may or may not use aerial photography, and they may or may not require additional right of way. The Preliminary Field Review Report should be developed in conjunction with the surveying requirements listed in Figure 5-12 on Page 5-29.

Aerial Photography Utilized Or Additional Right of Way Required

These projects require a control traverse. Projects will generally follow the steps below:

- planning and research,
- reconnaissance,
- establishment and numbering of the control points,
- preparation of the abstract,
- bench levels,
- establishment of the control survey,
- baseline,
- additional surveys as required by Design, Bridge, Hydraulics, or Right of Way.

Most of the above procedures or surveys are covered earlier in this manual and will not be repeated here. However, some procedures need to be revised or further explanation may be needed.

The numbering of the control points will be based on miles from the nearest paved road to the project site if mile markers are not present. The control monuments must be located outside the estimated construction limits.

As a general rule, an assumed elevation can be used at sites that have no delineated floodplains. If an assumed elevation is used, use 500 or 1,000 feet. Do not assume an elevation close to the actual elevation. Sites having designated floodplains should be tied to a USC&GS, NGS, or USGS bench mark. Hydraulics will make the final determination as to the datum to be used. The closures given in Chapter Four still apply.

The baseline is used for the profile and cross sections. The baseline is a design tool only. All ties to existing monumentation are made from the control traverse. Power poles, fences, and other topography can be made from either the baseline or the control traverse. All surveys requested by Hydraulics will be tied to the control traverse.

Bearings for off-system projects are to be based on a solar observation.

Aerial Photography Not Utilized And Additional Right of Way Not Required

These projects do not require a control survey. Projects will generally follow the steps below:

- planning and research,
- reconnaissance,
- bench levels,
- a conventional survey, and
- additional surveys as required by design, bridge, or hydraulics.

The conventional survey will be a closed traverse. The angular error is not adjusted, but coordinates are computed. If the linear error is less than 0.50 foot, the survey will not be balanced. All horizontal angles require one position or a set of horizontal angles. The difference between the direct angle and the reverse angle must be less than 20 seconds. The deltas and stationing remain as shown in the transit notes unless an error is found. This maintains the stationing in the field notes. A linear error greater than 0.50 foot must be located in the field notes or the field work. Use hubs and tacks to monument conventional surveys. Do not set iron pins or rebar to reference conventional surveys. These monuments may be confused with references to the right of way.

If the scope of the project changes and aerial photography or additional right of way is required, a control survey is necessary. The conventional survey is tied to the control traverse, using the methods outlined in Chapter Six and the previous section. The conventional survey is adjusted to fit the control survey. A weighted least squares adjustment should be used.

Additional Surveys

This includes the ties to property corners, property controlling corners, right-of-way monumentation, and private monumentation. The procedures for making these ties are given in Chapter Six. Also included in this category are additional survey requests made by various sections and bureaus of the Department.

Preliminary Survey Requirements

The requirements for preliminary surveys are summarized in Figure 5-12.

Project Manager's Recommendations

The field project manager's recommendations are a summary of his/her findings and conclusions regarding the project. The recommendations should include descriptions of the alignment, the terrain features, and all special conditions that should be considered during design of the project.

The recommendations are reviewed by the District and transmitted with their approval and comments to Headquarters.

Submitting the Survey

As significant elements of the survey are completed, submit them to the appropriate section. The sequence, in order of importance, is:

1. control traverse and computations, including photo control on photogrammetric surveys;
2. topography;
3. hydraulic surveys;
4. property ties; and
5. special requests.

Figure 5-12
Preliminary Survey Requirements

Activity	Project Type							
	1	2	3	4	5	6	7	8
Preliminary Field Review Report	X	X	X	X		X		
Planning	X	X	X	X				
Research	X	X	X	X	X			
Reconnaissance	X	X	X	X	X			
Set Control Monuments	X	X						
Bench Levels	X	X	X	X				
Secondary Levels	X	X	X	X				
Control Traverse	X	X						
Baseline	X							
Conventional Survey			X	X				
Tie Photo Control Points		X						
Tie Existing Monumentation	X	X			X			
Add Surveys as Requested	X	X	X	X	X			
Submission of Field Data P/S	X	X						
As Requested in the P.F.R.R.*						X	X	X

* Preliminary Field Review Report

Project Types:

1. New Location or Relocation — New Right of Way Required, or
   Bridge Replacement or Rehabilitation — New Right of Way Required
2. New Location or Relocation — New Right of Way Required and Aerial Photography, or
   Bridge Replacement or Relocation — New Right of Way Required and Aerial Photography
3. Overlay — No New Right of Way Required or Aerial Photography
4. Bridge Rehabilitation or Relocation — No New Right of Way Required or Aerial Photography
5. New Right of Way Only
6. Spot Improvements
7. Safety
8. Hydraulics

Table of Contents

Chapter Six — Property Corner Ties

Public Land Survey System 6-1

General 6-1

Overview of the Development of the Rectangular Survey System 6-1

Property Corner Ties 6-5

General 6-5

Research 6-7

Field Search 6-8

Numbering 6-9

Consultation with Right of Way 6-10

Corner Tie Procedures 6-10

Monument Descriptions 6-10
Procedures 6-10
Closed Traverse 6-12
Side Shot From Two Control Points 6-15
Side Shot from One Control Point Using Two Different Backsights 6-15
Side Shot from One Control Point and a Point On Line 6-15
Existing Right-of-Way Monumentation 6-16
Ties to the Horizontal Control Points (600 Series) 6-16
Computation of Traverses To Property Corners 6-17
Computation of Side Shots 6-17

Corner Recordation Act of Montana 6-17

Information Required to Complete a Certified Corner Recordation 6-18

Recording of a Certified Corner Recordation 6-18

Figures

6-1 Principal Meridians and Base Lines 6-3

6-2 Standard Parallels and Guide Meridians 6-2

6-3 Township Layout 6-4

6-4 Section Numbering within a Township 6-5

6-5 GLO Method of Subdividing Sections 6-6

6-6 Summary of Secondary Traverses and Side Shot Procedures 6-11

6-7 Traverse to Tie and Section Corner 6-13

6-8 Property Corner Ties to Traverse 6-14

6-9 Corner Recordation Act 6-20

6-10 Certified Corner Recordation Form 6-23

Figures (Continued)

6-11 Certified Corner Recordation — Example 1 6-26
6-12 Certified Corner Recordation — Example 2 6-27
6-13 Certified Corner Recordation — Example 3 6-28
6-14 Certified Corner Recordation — Example 4 6-29
6-15 Certified Corner Recordation — Example 5 6-30
6-16 Certified Corner Recordation — Example 6 6-31
6-17 Certified Corner Recordation — Example 7 6-32

Chapter Six
Property Corner Ties

The linear nature of highway surveys creates unique problems for the survey and the description of highway rights of way. First, the survey is frequently extended through several sections and more than one township. Second, the potential for the destruction of existing monuments is great. Third, the nature of the projects frequently results in the segregation of parcels that were contiguous. As a surveyor, you play an important role in locating and defining the land for acquisition, disposal, and use. Descriptions and acreage are based on the measurements and ties made by you.

A complete explanation of the principles of land surveying is beyond the scope of this manual. Several excellent publications covering the practice of land surveying are listed in Appendix B of this manual. Each field office will have available a copy of these BLM publications:

- Technical Bulletin No. 6, *Instructions for the survey of the Public Lands of the United States*, and
- *Restoration of Lost or Obliterated Corners and Subdivision of Sections.*

(See Appendix B for these and other references.)

Public Land Survey System

General

Montana is one of the thirty public land states originally surveyed under the direction of the United States General Land Office. In 1946, the General Land Office was abolished, and the administration, including surveys, resurveys, and maintenance of all survey records was officially passed to the Bureau of Land Management under the Cabinet Post of the Secretary of the Interior. Original and subsequent survey records are kept in the State Office of the Bureau of Land Management, Billings, Montana. At the time the rectangular survey system for the public land surveys reached Montana, rules outlining the survey methods, and the numbering and subdivision of the sections within each 36-square-mile township, were developed — for the most part — in their present form.

The purpose of the public land survey was to provide a way for the government to sell, or otherwise dispose of, lands in the largely unsettled West. The surveys were designed so that land could be described by a Patent Deed, in reference to the survey on the ground. This system formed the basis of all subsequent property surveys in the public land states. Monuments set during the original public land survey control subsequent surveys and locations of described properties.

Overview of the Development of the Rectangular Survey System

Surveys of the public lands have been conducted since the late 1700s. The first survey covered lands in Ohio. The public lands originally included lands turned over to the Federal Government by the original states and also include lands acquired from Native Americans. Other parts of the public

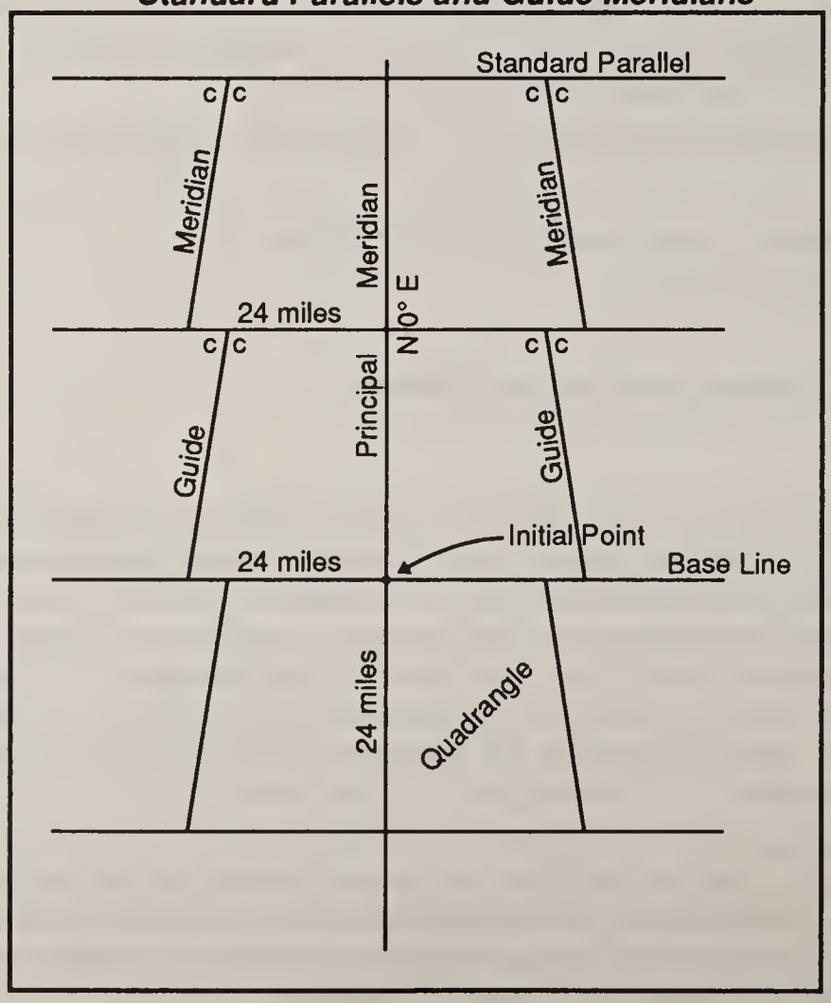
domain were obtained by purchase or simply by the taking. A large portion of the public lands in Montana was acquired by the Louisiana Purchase in 1803. Montana was admitted into the Union on November 8, 1889.

Public lands surveys of an area began with the establishment of the Initial Point. The rectangular surveys commenced at this point. Refer to Figure 6-1 on the next page. Montana has only one Initial Point. Some states (California, Wyoming, etc.) have more than one Initial Point. Other states (North Dakota, Nevada, etc.) have their Initial Point outside the boundaries of the state.

From the Initial Point two lines were established. They are known as the Principal Meridian and the Base Line. Along these two lines, quarter corners, section corners, meander corners, and other required monuments were set. The Principal Meridian was established north and south from the Initial Point. It is a true meridian. The Base Line extended east and west from the Initial Point.

Standard Parallels and Guide Meridians were then established. Refer to Figure 6-2. Standard Parallels extend east and west from the Principal Meridian. They are parallel to the Base Line. In Montana, Standard Parallels are generally located at 24-mile intervals north and south of the Base Line. Guide Meridians extend north from the Base Line or a Standard Parallel. Guide Meridians terminated with the establishment of a closing corner at the intersections of a previously established Standard Parallels. Quarter corners, section corners, meander corners, and other required monuments were established along the Standard Parallels and Guide Meridians. The linear error in the Guide Meridians was absorbed in the last half mile. With the surveys of the Standard Parallels and Guide Meridians complete, the boundaries of 24-mile tracts (quadrangles) of the Public Domain were established.

Figure 6-2
Standard Parallels and Guide Meridians



Township exteriors were surveyed next. Refer to Figure 6-3. This survey generally commenced on the southerly boundary of a quadrangle. A line was established northerly from a township corner for a distance of six miles. Along this line, quarter corners and section corners were established at intervals of forty chains. Township corners were established at six-mile intervals. Meander corners were also established as required. Then a random (trial) line was established from the newly established township corner easterly or westerly for six miles, depending upon conditions. The error in the

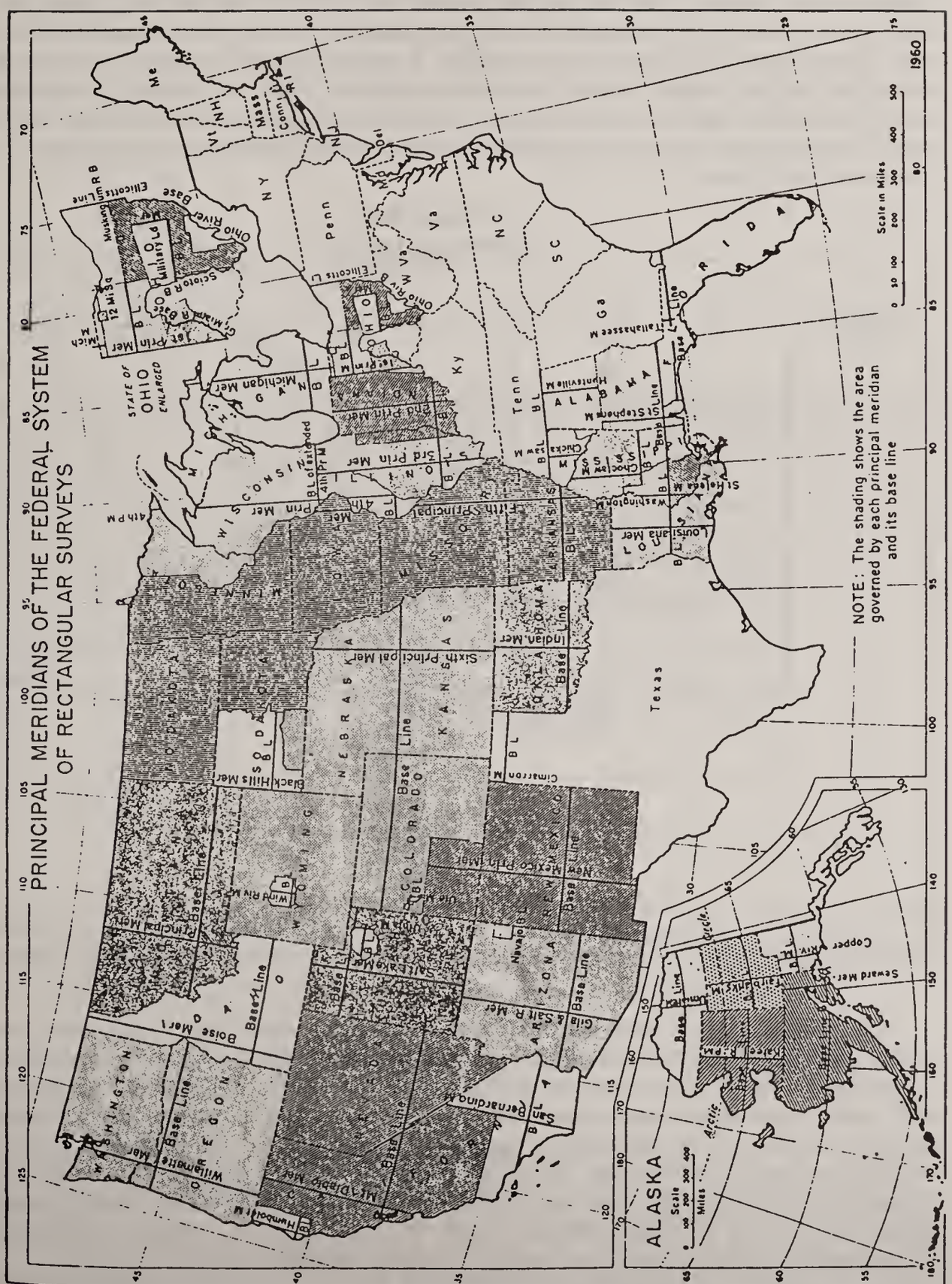
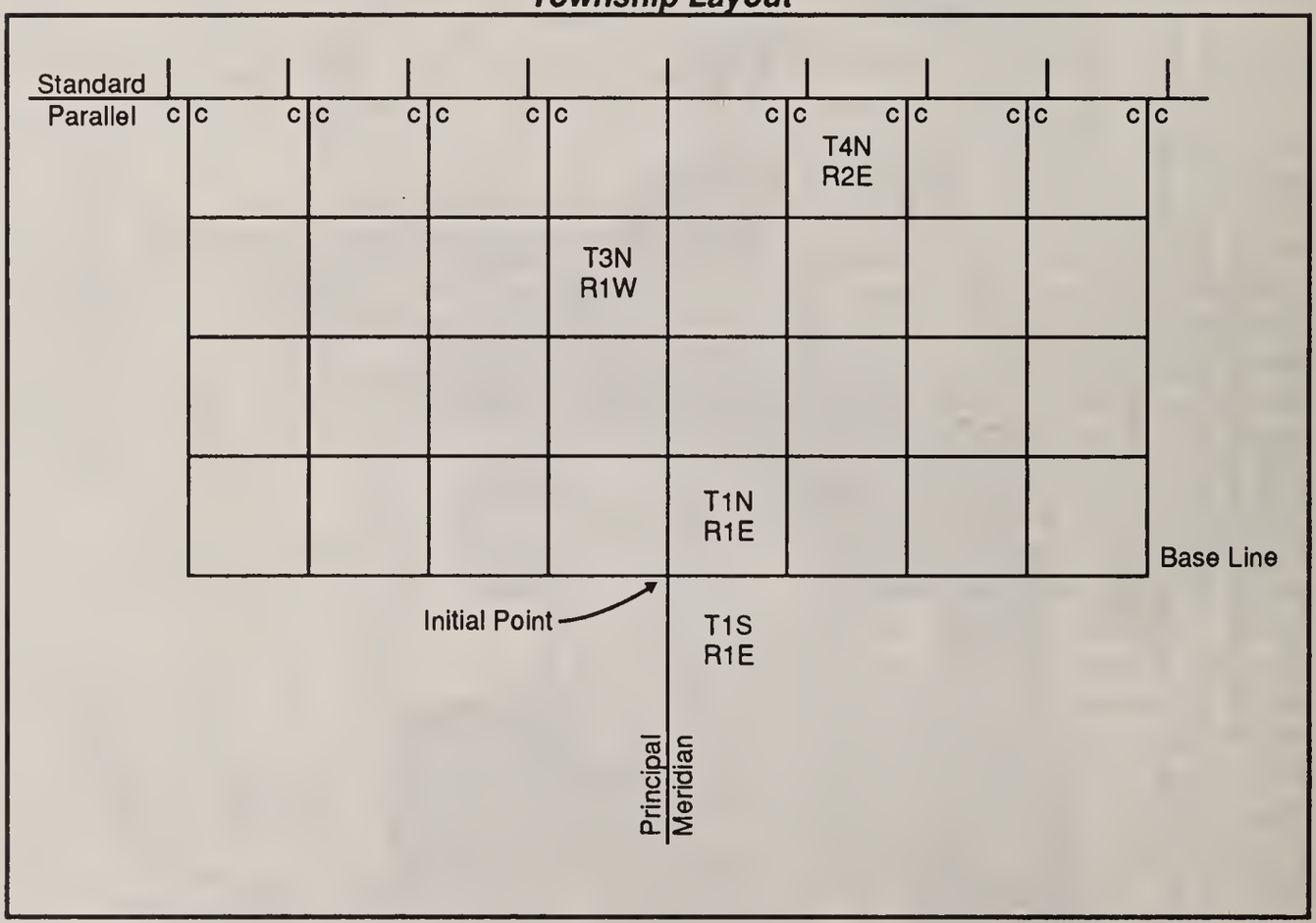


Figure 6-1
Principal Meridians and Base Lines

random line was determined, and a true line was calculated. The true line was then surveyed in the opposite direction of the just completed random line. The true line was monumented with the appropriate corners. Quarter corners and section corners were set at intervals of forty chains. The linear error in this six-mile line was placed in the last half mile. This scheme was repeated until the survey was six miles south of the next Standard Parallel. A true line was run northerly, and at the intersection of the Standard Parallel a closing corner was established. Again, any linear error was absorbed in the last half mile. This procedure was repeated until the quadrangles were subdivided into tracts of land six miles square. These tracts are referred to as townships. Townships are numbered in relationship to the Initial Point.

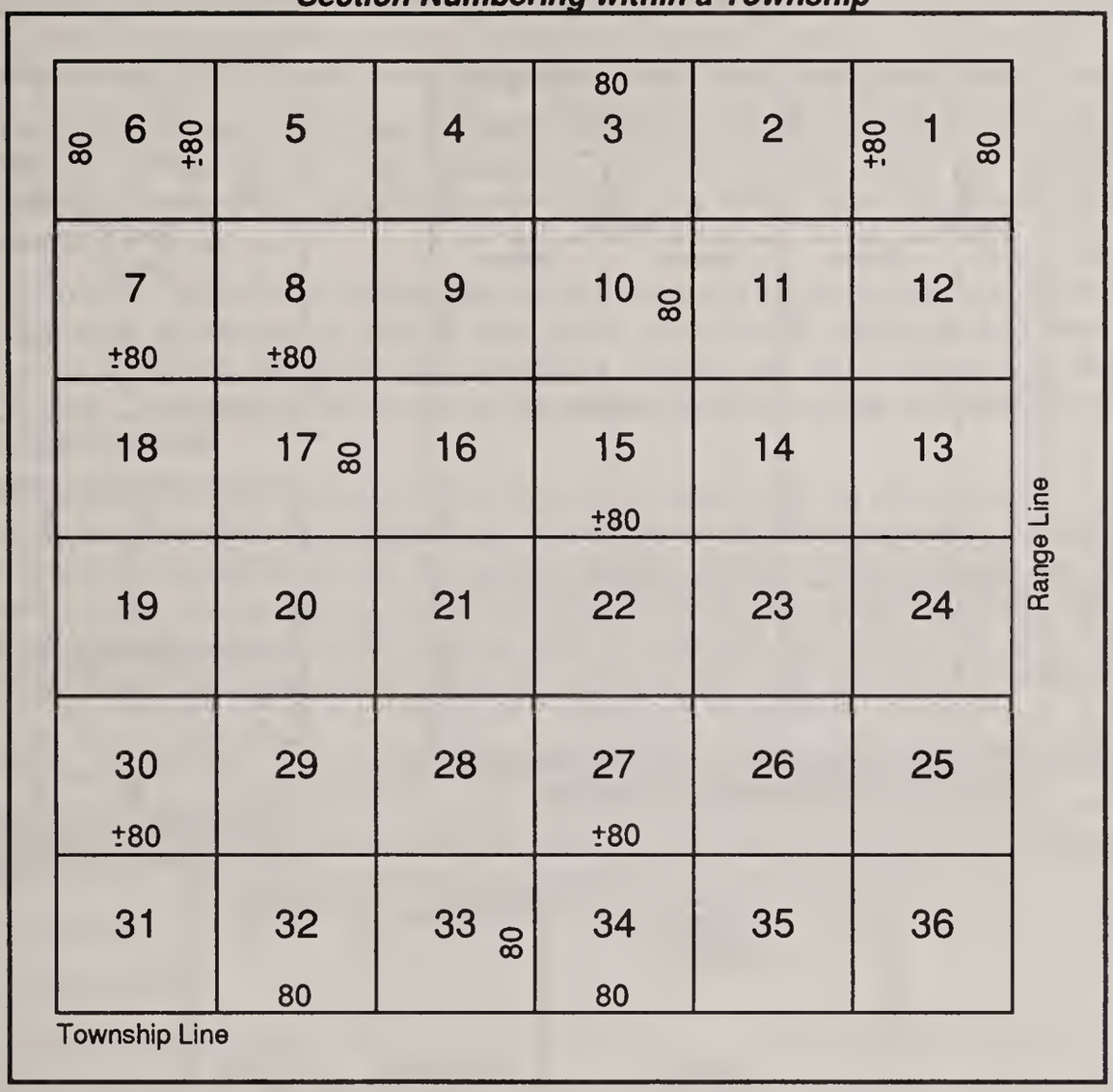
Figure 6-3
Township Layout



Townships were then subdivided into sections containing approximately 640 acres. Figure 6-4 shows the numbering of the sections within a township and the typical lengths of section lines within the townships. Not all section lines are 80 chains long. The procedure to subdivide the township was very similar to the method used to subdivide the quadrangles into townships. This will not be covered in detail. Refer to the references in Appendix B for this information. In general, all north-south section lines were set at 80 chains and quarter corners at 40-chain intervals. Meander corners were established where applicable. East-west section lines were close to 80 chains. Quarter corners were placed on line and at the mid-point in most cases. The linear error was absorbed in the last half mile between those sections adjacent to the northerly and westerly boundary of the township.

Figure 6-5 shows the GLO method of protraction, or their intent as to how the section is to be subdivided. Also given in the figure is the nomenclature used to describe parts of a section.

Figure 6-4
Section Numbering within a Township



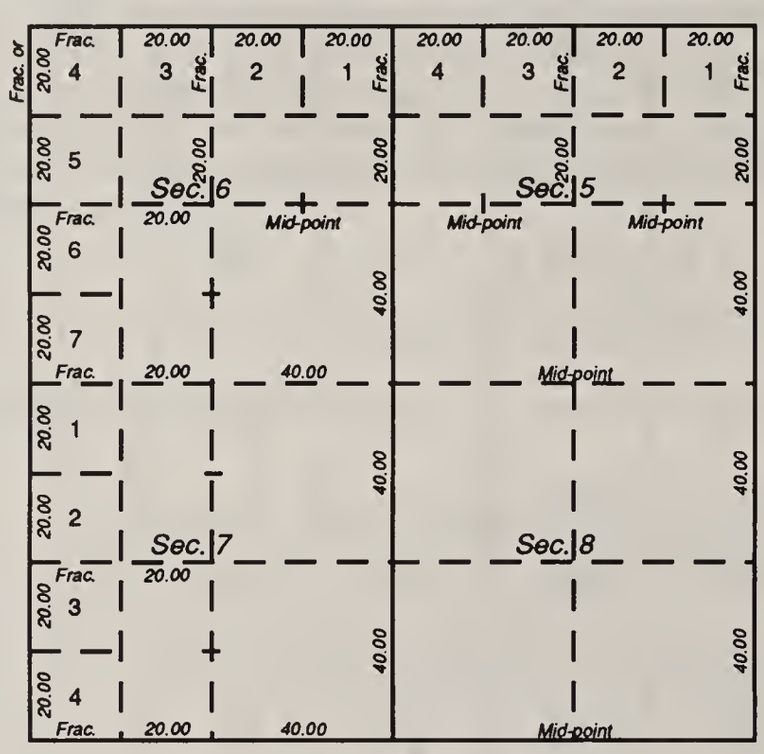
Most surveys conducted by the Department will require searching out and tying of monuments established by the General Land Office, the Bureau of Land Management, or Professional Land Surveyors, or monuments set by Department personnel from previous projects. It is necessary that the people searching for this monumentation are fully aware of the importance of this work.

Property Corner Ties

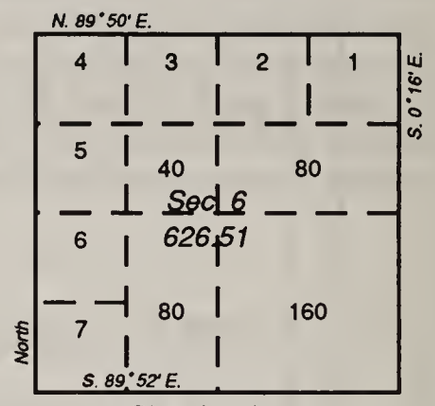
General

All projects that require additional right of way will require ties to found property corners and property controlling corners. For the purpose of this Manual, property controlling corners are section corners, quarter corners, meander corners, and the like. They monument the rectangular survey system. Property corners monument individual tracts of land, both private and public. Generally, Department personnel will not be required to reestablish lost or obliterated monuments. They should, however, tie all required found monuments.

Figure 6-5
GLO Method of Subdividing Sections



Showing Normal Subdivision of Sections



Showing Areas

Showing Calculated distances

40 Chains 160 Rods 2640 Feet NW 1/4 160 Acres		20 Chains W 1/2 NE 1/4 80 Acres		80 Rods E 1/2 NE 1/4 80 Acres
1320 Ft. NW 1/4 SW 1/4 40 Acres	20 Chains NE 1/4 SW 1/4 40 Acres	650 Ft. W 1/2 NW 1/4 SE 1/4 20 Acres	650 Ft. E 1/2 NW 1/4 SE 1/4 20 Acres	1320 Ft. N 1/2 NE 1/4 SE 1/4 20 Acres S 1/2 NE 1/4 SE 1/4 20 Acres
SW 1/4 SW 1/4 40 Acres 440 Yards	SE 1/4 SW 1/4 40 Acres 440 Yards	S 1/2 SE 1/4 80 Acres		

No single side shot tie will be used to tie property or property controlling corners. All property and property controlling corners must be tied such that the coordinate position is verified. The coordinate position of the property corner will be used to plot the corner and to compute the tie. Ties to centerline will be computed after Road Design has developed the final road alignment.

The plans will contain the control diagram and control abstract. The standard symbol for a control point is a triangle and dot. The coordinates of all found property corners will also be shown in the final right-of-way plans. Appropriate symbols should be used. A table will be used to label these coordinates.

The primary purposes for making ties are for orientation of the survey, reconstruction of the record location of the existing right of way, and/or acquisition of additional right of way. These surveys are an integral part of the land acquisition, disposal, use, and maintenance of our right-of-way records. These surveys are used to tie Department facilities to lines of the public land survey system.

The property surveys conducted by the Department begins with the office research of the record and is not completed until final right-of-way monuments are set. Some examples of monuments that may be tied to the control traverse are: section corners, quarter corners, meander corners, closing corners, witness corners, right-of-way monuments, reference pins, property corners, and in some cases existing centerline. Projects utilizing aerial photography also require ties to the 600 series control points. These photo control points are tied using the same procedures used to tie property corners.

Monuments tied are generally adjacent to or near the project. Property controlling corners may be an exception. Reference pins set by the Department are not property corners, but they are vital in the reconstruction of the original centerline and right of way. They will be tied as though they were property corners. Ties to property corners generally follow the steps below:

- Research.
- Field search.
- Numbering scheme.
- Consultation with the Right-of-Way Bureau as to which property controlling corners and/or property corners are required.
- Ties to found and possible monuments from the control traverse.
- Computation of monuments tied to the control traverse.
- Perpetuation of the required property controlling corners.
- Preparation and filing of the corner recordation form.
- Setting of any new or required right-of-way monuments.

Research

In order to make the ties to the property controlling corners, property corners, photogrammetry control points, right-of-way monumentation, and reference monuments needed by the Department, those making the surveys must fully understand the contents of this chapter.

Research, in general, was discussed in Chapter Five. Research as it pertains to ties to property corners is covered in detail below. Research is the first action in the recovery operation. It is of utmost importance to the successful recovery and identification of lines and corners. Most current highway projects follow the general alignment of existing roads. The field project manager or his/her

designee is responsible for ensuring that this research has been accomplished, prior to any field search. It is a waste of time to search for corners before the research has been completed. This research will be thorough. Research should include:

- A request to the appropriate District for copies of all applicable GLO and BLM field notes and plats. The District may request this information from the BLM on microfilm. Microfilm is substantially cheaper than paper copies.
- Railroad maps and plats. This information will generally not be available to the field project manager. Do not overlook this source of vital information. A request for railroad plats should be made to the Photogrammetry and Survey Section.
- The records accumulated during the survey and construction of the existing facilities. This includes existing plans (construction and right of way) and original field notes. The original field notes are maintained in Helena. Unfortunately, most of the early survey notes were microfilmed and in most cases are now unreadable. The District should contact Helena for this information.
- Right-of-way documents. The Right-of-Way Bureau maintains files of deeds and easements, court orders of conveyances, contracts, leases, and sales of excess lands.
- Files of all aerial photography and control surveys are maintained by the Department. The project area may have been photographed several times over a period of years, and a comparison of earlier and current photography can become a valuable tool in the recovery of monuments.
- Individual Forest Service Districts or the Supervisor Office maintain records of surveys for Forest Service land. The Forest Service should be contacted if the project is near National Forests.
- The land office records of Indian Tribes should be checked for projects on or near Indian Lands.
- The county courthouse contains a great deal of information. Items that should be researched (and copied) include corner recordation forms, subdivision plats, certificates of survey, deed exhibits, deeds, county journals, county surveyor field notes and sketches, county road documents, etc.
- United States topographic maps. These maps should be obtained from the District or at local sporting goods stores.

Field Search

The field search for all required monuments is an important aspect of all projects requiring ties to property corners and property controlling corners. Persons with limited corner search experience will not be placed in charge while searching for property controlling corners. Remember that corner recordation is required by Montana statutes. It may be advisable for the District to tie all found property corners along the project, but retain a consultant for the tying of the property controlling corners. This work should be scheduled only when the ground is bare. Corners cannot be located under two feet of snow.

The method used to locate existing monumentation will depend upon the situation and if a property corner or property controlling corner. In general, all existing monuments along or near the existing right of way as shown on certificates of survey, deed exhibits, subdivision plats, right-of-way plans, and construction plan must be located. Metal locators are required. If the District is

planning to tie the property controlling corners, a search will be made of all these corners within one-half mile on each side of the project. Bridge projects where additional right of way is needed require a search and ties to a sufficient number of property controlling corners. Right of Way should be consulted as to which corners are needed.

Much time and expense have been committed to the research of materials to aid in the field search for monuments. If properly studied, many of the search areas should be fairly well defined. Determine search areas for all corners. In the case of property controlling corners, use care in searching; do not destroy any evidence in the process. Look for the monuments as called for in the record or a monument traceable to the original. In other areas, where there is a lack of physical evidence, the search area may need to be reduced by measurements from found corners. A hip chain and hand compass are very useful.

The first step in the actual search of a property controlling corner may be to contact the landowners, not only to let them know what is being done and to obtain their permission to do it, but to get from them as much information as possible. In many cases, the landowner can direct the surveyor to the spot where the monument is or was located. The landowner's opinion is not always correct, but it certainly should be considered in the acceptance or rejection of corner evidence. The surveyor should be very noncommittal at this time. Do not express an opinion. Let the landowner discuss the situation.

A rule in searching for monuments is to look for the easiest corners first. Each monument found should be flagged to make it less difficult for others to locate. Many corner monuments in Montana, particularly those under county roads, have been replaced with iron pins, rebar, or pipes. A metal locator is essential.

When all the "easy" monuments have been located, flagged and tentatively verified, physical measurements may be required to find the remaining monuments. If a monument is not recovered, the notes should reflect the type of search that was conducted, what was found, the extent of the search, and any other data that might help to prove the search was properly conducted and made in the correct area. Refer to sample field notes in Appendix A.

Recovery of a sufficient number of monuments within a platted subdivision is required to adequately describe portions of the subdivision that will be severed by the highway right of way. Not all lot or tract corners may be required by Right of Way.

Numbering

Each survey point will be assigned a point number. This number will be used in the field notes. The field notes will contain a complete description of all monuments. To avoid errors in numbering of reference pins and right-of-way monuments, a stake or lath should be driven next to the monument with a number that coincides with the number used in the field book. The following point numbers are reserved.

- Milepost and letter are reserved for control traverse points.
- AP and a letter are reserved for angle points associated with the baseline.
- 1-99 are assigned to random traverse points not associated with the control traverse.
- 100-200 are reserved for property controlling corners.
- 200-499 are reserved for property corners, reference pins, right-of-way monuments, ties to centerline, etc.
- 500-550 are reserved for vertical photo control points.

- 600-650 are reserved for horizontal photo control points.

This numbering system will be more useful as the availability of data collectors increases.

Consultation with Right of Way

Right of Way should make the determination as to which property controlling corners must be tied. Generally, this will be all property controlling corners within one-half mile on each side of the project. Ties to all found corners may not be required. Right of Way may require corners not found in the initial field search. If this is the case, the District should consider using a consultant for this work. This consultation is not required if a consultant is to be utilized. The consultant will work directly with the District.

Corner Tie Procedures

The procedures for tying property corners and property controlling corners from a control traverse are presented in this section. A summary of the requirements for ties to property corners and property controlling corners (secondary traverse) is presented in Figure 6-6.

Monument Descriptions

All monuments (property and property controlling corners) tied must be described fully in the field notes. The location and description of monuments provide the basis for retracement of the property lines. This description will include the size, kind, and type of monument. Be specific in describing the monument: iron pin, pipe, rebar, etc., with the size and other identifying information. The field notes will indicate whether a monument was found or set. Found means that monument was there prior to the current survey. Set means that monument was established during the course of the current survey. This must be noted for all points occupied during the course of any survey. The field notes will contain a sketch showing all stamping of all caps tied. Rubbings may be used instead of the sketch.

Procedures

On projects that require a control traverse, the following must be tied:

- Right-of-way monuments.
- Reference pins.
- Property corners.
- Property controlling corners.
- Existing centerline in certain cases.
- The 600 series photo control points (photo projects only).

The above monuments will be tied to the control traverse using the methods and procedures given below. As noted in Chapter 4, elevations must be determined for all photo control points (500 and 600 series). Intermediate foresights in conjunction with differential levels are not to be used. Trigonometric levels may be used instead of differential levels to determine the elevations of the photo control points, but strict adherence to procedures previously discussed must be maintained.

Figure 6-6
Summary of Secondary Traverses and Side Shot Requirements

I. Horizontal.
   1. Traverse.
      A. Distance Requirements.
         1. Initial backsight distance recorded.
         2. Final foresight distance recorded.
         3. Manual total station — one set of zenith angles and slope distance.
         4. Automatic total station — horizontal distance direct and reverse faces. Difference equal to or l than 0.02 foot.
      B. Angle Requirements.
         1. Closing angle required.
         2. Two positions at all traverse points.
            a. Difference between direct and reverse equal to or less than 20 seconds.
            b. Difference between a position and the mean of the two positions must be equal to or less than 10 seconds.
         3. Distance greater than 4000 — should consider three positions.
      C. Closure.
         1. Maximum angular error equal to or less than $10'' \sqrt{\text{Number of Setups}}$.
         2. Maximum linear error, after satisfying the angular condition, is $0.10' \sqrt{\text{Total Distance}/1000}$, but in no case will it be greater than 0.50 foot.
      D. Coordinates computed by compass, Crandall, or least squares.
   2. Side Shots.
      A. Distance Requirements.
         1. Backsight distance recorded.
         2. Manual total station — one set of zenith angles and a slope distance. If possible, one dista recorded in feet and one in meters.
         3. Automatic total station — horizontal distance direct and reverse faces.
            a. Difference equal to or less than 0.02 foot.
            b. If possible, one distance recorded in feet and one in meters.
      B. Angle Requirements.
         1. Distance less than 1500 feet. One position, but the difference between the direct and reve readings must be equal to or less than 20 seconds.
         2. Distance greater than 1500 feet. Difference between a position and the mean of the two positi must be equal to or less than 10 seconds.
      C. Radial Difference. Less than or equal to 0.25 foot.
      D. Coordinates computed by a mean or least squares.

II. Maximum Vertical Errors (500 and 600 photo control points).
   1. Differential level loop — 0.10 foot.
   2. Difference in elevation between differential levels to the point and trigonometric levels to the same point — 0.10 foot.
   3. Reciprocal levels — 0.10 foot total vertical error.

Monuments may be tied either directly or indirectly. Direct ties are made by measuring the length and direction of the property lines. Indirect ties made to a coordinate system are generally more efficient and accurate than direct ties. It is the preferred method. If the project is not controlled by a coordinate system and direct retracement would be impractical due to vegetation, fences, and other improvements, a local coordinate system should be used. The coordinate system must be consistent through the entire length of the project in order to provide the positional relationships between the survey line and the property corners.

Direct ties are made at the intersection of the section or property line and the survey centerline. The intersection station is established by "straddle points" on both lines and finally located by string-lines. The station, angle of crossing, and distance to each of the property corners are required to complete the tie. If the crossing occurs on a curve, the intersection point should be established on the semi-tangent.

All property corners or property controlling corners will be tied to the control traverse. It is not necessary to establish lost or obliterated reference monuments, right-of-way monuments, property corners, or property controlling corners. Tie all found corners. Right of Way may request additional field work. In cases of extensive obliteration of property controlling corners, it is advantageous to have this work done by a Professional Land Surveyor.

There may be more than one found monument at a corner position. A common situation is when a surveyor has found the record stone and set a rebar and cap next to the stone. In this case, if it is clear from the recordation form that the stone occupies the original location, tie the stone and measure a distance to the cap. Indicate the general direction from the stone to the cap. The cap does not need to be tied. The stone is the corner; the cap is a reference to the corner. In all other cases tie and describe all monuments found. If, in the record search process, you have developed an opinion as to which corner has the most validity, then state the facts that support that opinion in the field notes.

Instruments having a least count or a DIN value greater than 10 seconds will not be used. There are several approved methods to tie property controlling corners and property corners to the control traverse. Approved methods are:

- Closed traverse.
- Side shot from two control points.
- Side shot from one control point and a point on line (POL).
- Side shot from one control point, but different backsights are utilized.

The closed traverse or side shots from two control points are the preferred methods.

Closed Traverse

The traverse will commence at one control point and close on a different control point. The traverse will not commence and end at the same control point. The traverse will be as direct as possible. The traverses should be less than four miles. Refer to Figures 6-7 and 6-8. The traverse should be from tripod to tripod. Side shots may be taken during the course of a traverse to a property controlling corner, property corner, or a 600 photo control point, but correct procedures must be utilized. Side shots are useful to eliminate short legs in a traverse or to tie a point that can not be occupied, such as a section corner under an existing fence.

Horizontal Angle Requirements. In all cases the closing angle must be turned. A minimum of two positions of the horizontal circle will be used. The party chief should consider turning three positions if the distances are greater than 4000 feet. The difference in the angle measured direct and

reverse must be equal to or less than twenty seconds. If not, return that position. Any position greater than 10 seconds from the mean must be also be returned. Only the position rejected needs to be returned.

Distance Requirements. Distances recorded will depend upon the type of instrument used. In all cases, distance ahead will be recorded. Backsight distances are optional. Manual total stations require the recording of a slope distance and a set of zenith angles. The zenith angles must show consistency. The note keeper must inform the instrument operator if additional zenith angles are required. If an automatic total station is used, the displayed horizontal distance can be recorded, provided the distance is recorded in the direct and reverse mode. The maximum difference between the direct and reversed horizontal distance must be less than or equal to 0.02 foot.

Figure 6-7
Traverse to Tie & Section Corner

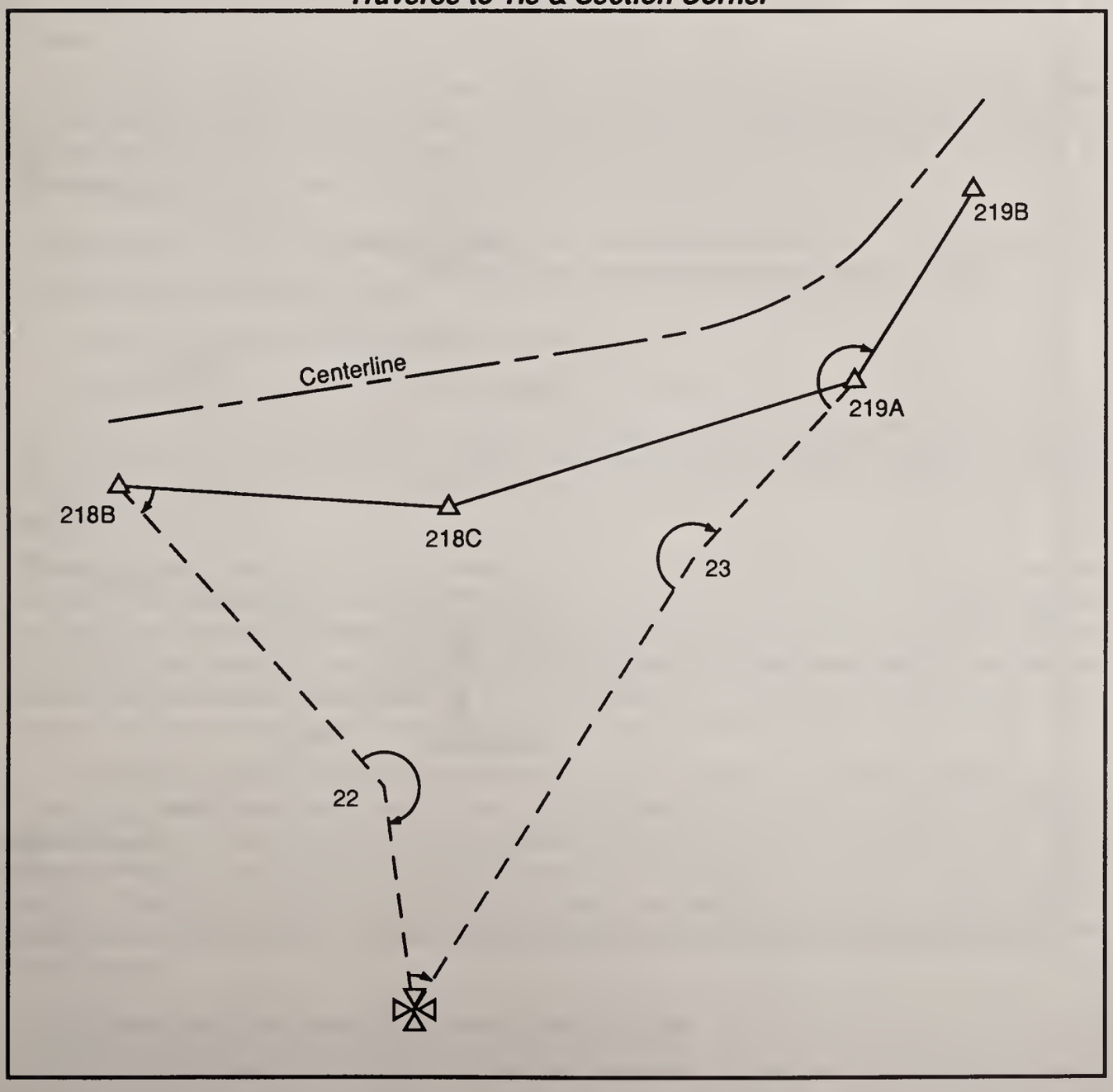
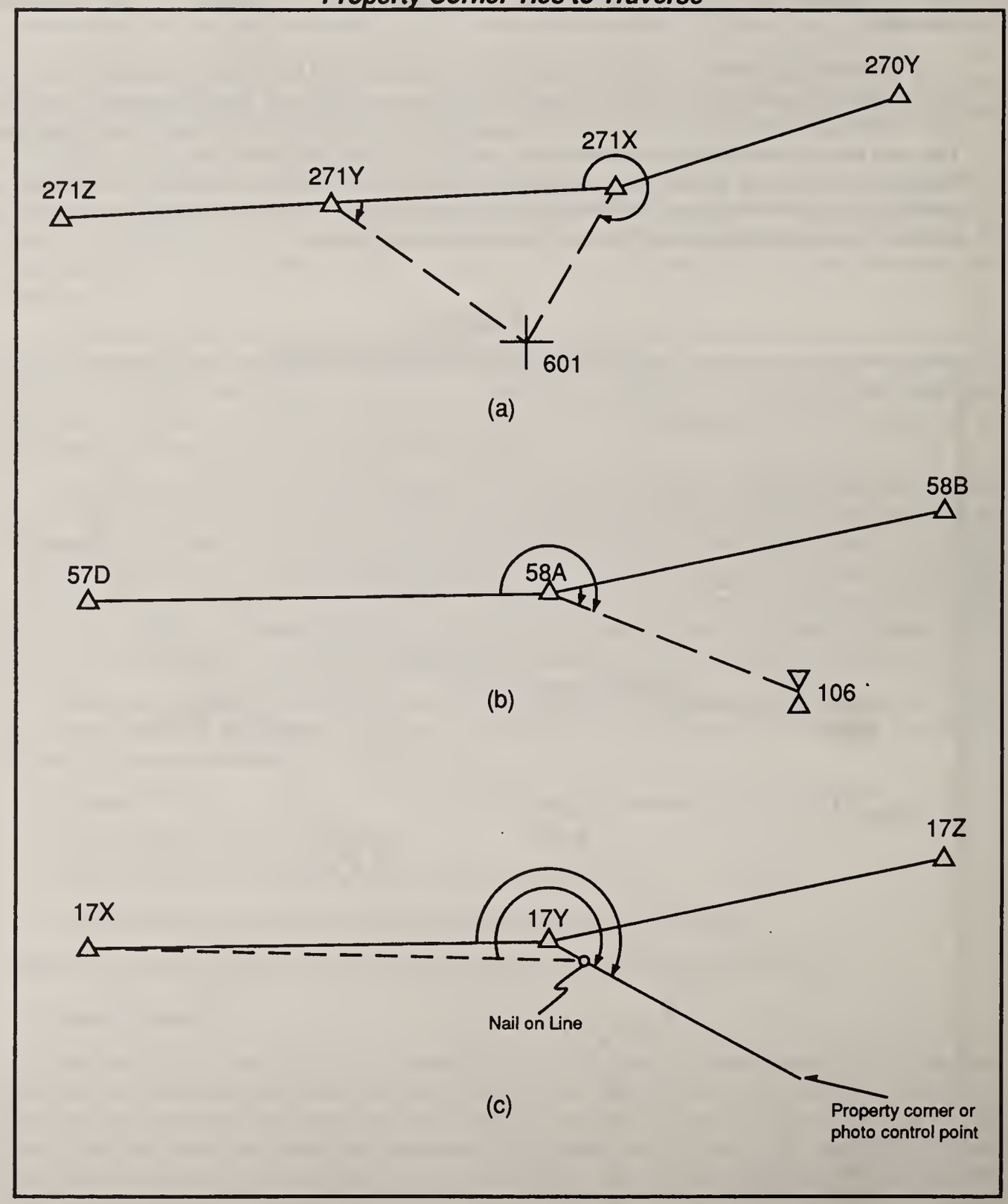


Figure 6-8
Property Corner Ties to Traverse



The distance to the initial backsight and the final foresight will be recorded. This provides a check that the initial backsight and the final foresight were to the correct control points. Refer to the sample notes in Appendix A. The traverses must close within the expected tolerances stated in Chapter Four.

Side Shot From Two Control Points

Horizontal angle requirements — if the distance to the foresight is less than 1500 feet: One position of the horizontal circle will be used. The difference in the angle measured direct and reverse must be equal to or less than twenty seconds. Prism poles may be use, but if a prism pole is used, the bubble must be checked and adjusted.

Horizontal angle requirements — if the distance to the foresight is greater than 1500 feet: Two positions of the horizontal circle will be used. The difference in the angle measured direct and reverse must be equal to or less than twenty seconds. If not, return the position. A position greater than 10 seconds from the mean must be also be returned. Only that position rejected needs to be returned.

The distance requirements are the same as the traverse, except that the distance to all backsights must be recorded to provide a check. Refer to the sample notes in Appendix A and Figure 6-8(a). The maximum radial difference of the property corner or the property controlling coordinates as computed from both control points must be equal to or less than 0.25 foot.

Side Shot from One Control Point Using Two Different Backsights

This method is used ***only*** when:

- a traverse would be time consuming or impractical, or
- the property corner cannot be seen from two control points.

The horizontal angle requirements are the same as if two control points were used, but the distance requirements to the foresight are different. This is necessary to provide a check on the coordinates of the monument tied. If the guidelines for this method are not followed, this procedure will be eliminated as an option.

A manual total station requires the recording of one horizontal position if the distance is less than 1,500 feet. Two positions are required if the distance is greater than 1,500 feet. A set of zenith angles and a slope distance using both backsights is required in all cases. Prior to the second backsight, the height of the prism ***must*** be changed and the optical plummet of the instrument verified. A second set of zenith angles is recorded along with the new slope distance. The second slope distance should be recorded in meters if it can be easily accomplished; otherwise record the slope distance in feet.

An automatic total station requires the information above, except that horizontal distances must be recorded in the direct and reverse modes. The difference between the two horizontal distances must be equal to or less than 0.02 foot. Prior to using the second backsight, the height of the prism on the foresight is changed, and the optical plummet of the instrument is verified. The second set of distances should be recorded in meters if it can be easily accomplished. Refer to the sample notes in Appendix A and Figure 6-8(b). The maximum difference in the coordinates must be equal to or less than 0.25 foot.

Side Shot from One Control Point and a Point On Line

This method is used if a traverse would be time consuming or impractical, or the corner cannot be seen from two control points. The corner is tied from a control point; then it is tied from a point

on line. A nail is set on line with the corner at a random distance. The instrument is moved to this nail. A backsight is taken to a different control point, and the required information is recorded again to the same corner. The horizontal distance between the control point and the nail must be measured. This distance would typically be 4 to 10 feet. A chain is used to measure this random distance. Refer to Figure 6-8(c) and sample notes in Appendix A.

At the control point and the point on line a manual total station requires the recording of one horizontal position if the distance is less than 1,500 feet. Two positions are required if the distance is greater than 1,500 feet. A set of zenith angles and a slope distance from both the control point and the point on line are required in all cases. One distance may be recorded in feet and the other in meters if this is easily accomplished.

An automatic total station requires the information above, except the horizontal distances must be recorded in both the direct and reverse modes. The difference between the two horizontal distances will be equal to or less than 0.02 foot. The maximum difference in the computed coordinates from the control point and the random point must be equal to or less than a radial error of 0.25 foot.

Existing Right-of-Way Monumentation

Different combinations of monuments may be found. One common situation is a found reference pin and a found right-of-way monument at breaks in the right of way or at a PC or PT. In this case, the reference pin is tied using the approved procedures. In addition a horizontal distance is measured to the back of the concrete right-of-way monument or to the center of the right-of-way monument in the case of an iron pin, pipe, rebar, etc. This distance should be recorded to the nearest 0.10 foot. A topography shot (single angle and distance) to the approximate centerline is required. Topography shots should be recorded to the apparent centerline at selected intervals along long circular curves as well. Do not monument record right of way. Tie found monuments only. Monuments must be fully described in the notes.

Another situation is where only right-of-way monuments are found. In this case, tie the monument using the approved procedures. Record a topography shot to the approximate centerline, and along long circular curves. It is not necessary to set monuments, hubs and tacks, etc., at record right-of-way breaks. The Right-of-Way Bureau will compute these positions. Tie all found monuments.

Some existing projects may not have existing reference pins or right-of-way monuments. They may have not been set, or they have been "farmed out." In this case the apparent centerline may be the best evidence of the right of way along with any structures such as bridges. This is probably the only situation where the centerline may be used to establish the right of way. Photogrammetry and Survey and Right of Way should be consulted. In all other cases, if centerline is required, the reference pins and/or the right-of-way monumentation is used.

Ties to the Horizontal Control Points (600 Series)

The 600 series are photogrammetry, horizontal control points. The rectangular coordinates and the elevations of these points are required for mapping. The coordinates (northing and easting) will be obtained using the procedures above. Elevations can be determined using differential levels, trigonometric levels, or a combination of the two methods. In all cases the elevations must be capable of being verified. This can be accomplished by:

- A closed level circuit that has the vertical error proportionately distributed. Refer to Chapter 4.
- Differential levels to the photo control point in conjunction with trigonometric levels to the same photo control point.

- Trigonometric levels from two control points.
- Reciprocal trigonometric levels if the photo control point was tied from one control point.

If the second method above is used, then the elevation of a photo control point based upon differential levels to the point and trigonometric levels to the same point must agree within 0.10 foot. The elevation determined by differential levels will be held. If the elevation of a photo control point is obtained from two control points using trigonometric levels, the two elevations must agree within 0.10 foot. Hold the mean elevation. The maximum vertical error in reciprocal trigonometric levels is 0.10 or less. If the total vertical error is equal to or less than 0.10, the mean elevation is to be used.

Trigonometric levels require the measurement of HIs and HSs. These heights should be recorded to the nearest 0.01 foot. The vertical distance must be corrected for the combined effect of curvature and refraction. This correction can be done by setting the switches on the EDM or by use of a formula, but not both. The general formula for determining the elevation of a photo control point is:

Elevation = Elevation at Instrument + HI + (VD + c&r) - HS

Attention must be given to the sign of the vertical distance. Uphill the sign is positive; downhill is negative. The combined effect of curvature and refraction can be assumed to be:

$$c\&r = 0.0206\left(\frac{HD}{1000}\right)^2$$

The vertical measurements recorded will be determined by the type of instrument used. A manual total station requires a set of zenith angles and the slope distance. The field notes must indicate the setting of the curvature and refraction switch. The notekeeper should verify consistency in the zenith readings. An automatic total station requires the recording of a direct and a reverse vertical difference as well as a direct and reverse zenith angle. This difference must be equal to or less than 0.05 foot.

Computation of Traverses to Property Corners

The procedure to compute and adjust a traverse to property or property controlling corners is identical to the control traverse. The control traverse is balanced prior to the property corner traverse. In other words, the balanced coordinates of the control points are held. The closing angle is measured, the angular error (if less than given in Chapter 4) must be determined and adjusted, and the closure after the angular error has been distributed must meet the tolerances in Chapter 4. If this tolerance is satisfied the traverse is adjusted using either the compass or Crandall adjustment. A least squares adjustment may also be used. If the angular error is excessive or the traverse closure is excessive, do not continue. Find the error in the field or in the calculations. The balanced coordinates are then used to determine the bearings and distances between the traverse points.

Computation of Side Shots

The coordinates of monuments tied by side shots will be determined based upon a mean of the coordinates or as determined by a least squares adjustment.

Corner Recordation Act of Montana

Montana was one of the first states to enact a statute that addressed the perpetuation of property corners and property controlling corners. The Corner Recordation Act (70-22-104) requires the filing of a corner recordation form for every controlling property corner used in a survey "unless the corner and its accessories are substantially as described in an existing corner record filed in accordance with the provisions of the act."

This statute (Corner Recordation Act) can be found in Figure 6-9 at the end of this chapter followed by a sample Certified Corner Recordation Form (Figure 6-10) and several examples of filed recordations (Figures 6-11 through 6-17). Refer to these examples when a recordation is to be completed by Department personnel. A pad of blank corner recordation forms may be obtained from M.A.R.L.S. (Montana Association of Registered Land Surveyors, Box 4112, Missoula, MT 59806).

Information Required to Complete a Certified Corner Recordation

The complete history of the monument (the record) should be included. This information is usually obtained from the original survey or resurveys conducted by the Bureau of Land Management. Information obtained from a previous recorded corner recordation will also be included as part of the record. The record information is then followed by what you found, and what was done (set) to perpetuate the corner location. The record, found, and set information will be recorded in the field notes at the time the corner is found. This simplifies the completion of a certified corner recordation. Refer to the sample notes in Appendix A.

Recording of a Certified Corner Recordation

Only on rare occasions will existing corner forms show the current condition. When a controlling property corner is in need of restoration or remonumentation, contact the Department's Professional Land Surveyor (PLS) for assistance. The PLS may delegate authority to do remonumentation. If this work is delegated, completion of the certified corner recordations is the field crew's responsibility. The completed, signed recordation form is then forwarded to the Photogrammetry and Survey Section in Helena, along with the GLO field notes and the appropriate Department field notes. The District is encouraged to use a word processor to prepare the corner recordation.

All controlling property corners that are not in good condition and which are not exclusively identifiable will be rehabilitated or remonumented. The purpose is to leave the monument in such physical condition that it remains as permanent as possible and may be readily found. Corners will typically be remonumented with a 3 1/4-inch aluminum cap attached to a 2 1/2-inch x 30-inch flared aluminum pipe, or with a cap set in concrete or rock outcrop. When remonumenting a corner location, such as a 1-inch pipe or poorly marked stone, the new monument will replace the exact position of the original and the original monument will be buried upside down and alongside the new monument. The corner recordation form will clearly state what was done with the original monument.

Accessories to the corner, such as a scribed Reference Monument (a tree), a survey witness post with a decal, and/or reference monuments may be set to aid in the location and perpetuation of corners. If the party chief believes the possibility exists the monument will be destroyed, then reference monuments will be set and shown in the field notes and on the corner recordation form. If a corner recordation is being prepared for a BLM monument, set during an unapproved survey, reference monuments are required. The recordation must show these references and indicate the BLM survey is not approved. The reference monuments are typically an approved 2-inch aluminum cap stamped RM with the number, a punch mark, the distance, and the year. These reference monuments will be tied by a compass bearing and a horizontal distance. The party chief should verify the correct declination is used. All controlling property corners that will be disturbed by construction will be referenced prior to construction, and a corner recordation form showing the references will be prepared. This form will be complete in every detail.

The State has an obligation to perpetuate the position of all property corners that will be destroyed by construction. In the case of property corners that are not tied to a control traverse, references will need to be set and a corner recordation form filed. If the corner was properly tied to

the control traverse, and the coordinates of the property corner are shown on the right-of-way plans, then references will not be required.

Figure 6-9
Corner Recordation Act

TITLE 70
PROPERTY

CHAPTER 22
CORNER RECORDATION ACT
SURVEYS AND COORDINATES

Part 1 — Corner Recordation Act

Section

70-22-101. Short title.
70-22-102. Purpose.
70-22-103. Definitions.
70-22-104. Filing of corner record required.
70-22-105. Filing permitted as to any corner or accessory.
70-22-106. Filing of records on corners established before the effective date.
70-22-107. Form and contents of record — board to prescribe.
70-22-108. Corner records to be certified.
70-22-109. Duties of county clerk.
70-22-110. Surveyor to rehabilitate monument.

Part 1
Corner Recordation Act

70-22-101. Short title. This part may be cited as the "Corner Recordation Act of Montana."

70-22-102. Purpose. It is the purpose of this part to protect and perpetuate public land survey corners and information concerning the location of such corners by requiring the systematic establishment of monuments and recording of information concerning the marking of the location of such public land survey corners and to allow the systematic location of other property corners thereby providing location and identification of ownerships and thereby eliminating the repeated necessity for reestablishment and relocations of such corners where once they are established and located.

70-22-103. Definitions. Except where the context indicates a different meaning, terms used in this part will be defined as follows:

(1) A "property corner" is a geographic point on the surface of the earth and is on, a part of, and controls a property line.

(2) A "property controlling corner" for a property is a public land survey corner or any property corner which does not lie on a property line of the property in question but which controls the location of one or more of the property corners of the property in question.

Figure 6-9 (Continued)
Corner Recordation Act

(3) A "public land survey corner" is any corner actually established and monumented in an original survey or resurvey used as a basis of legal description for issuing a patent for the land to a private person from the United States government.

(4) A "corner," unless otherwise qualified, means a property corner or a property controlling corner or a public land survey corner or any combination of these.

(5) An "accessory to a corner" is any exclusively identifiable physical object whose spatial relationship to the corner is recorded. Accessories may be bearing trees, bearing objects, monuments, reference monuments, line trees, pits, mounds, charcoal-filled bottles, steel or wooden stakes, or other objects.

(6) A "monument" is an accessory that is presumed to occupy the exact position of a corner.

(7) A "reference monument" is a special monument that does not occupy the same geographical position as the corner itself but whose spatial relationship to the corner is recorded and which serves to witness the corner.

(8) A "registered surveyor" is a surveyor who is registered to practice land surveying under Title 37, chapter 67, and has a paid-up license for that calendar year or who is authorized under Title 37, chapter 67, to practice land surveying.

(9) The "board" is the board of professional engineers and land surveyors, provided for in 2-15-1873.

70-22-104. Filing of corner record required. A surveyor shall complete, sign, stamp with his seal, and file with the county clerk and recorder of the county where the corner is situated a written record of the corner establishment or restoration to be known as a "corner record" for every public land survey corner and accessory to such corner which is established, reestablished, monumented, remonumented, restored, rehabilitated, perpetuated, or used as control in any survey by such surveyor and within 90 days thereafter unless the corner and its accessories are substantially as described in an existing corner record filed in accordance with the provisions of this part.

70-22-105. Filing permitted as to any corner or accessory. A surveyor may file such corner record as to any property corner, property controlling corner, reference monument, or accessory to a corner.

70-22-106. Filing records on corners established before the effective date. Corner records may be filed concerning corners established, reestablished, or restored before July 1, 1963.

70-22-107. Form and contents of record — board to prescribe. The board shall by regulation provide and prescribe the information which shall be necessary to be included in the corner record, and the board shall prescribe the form in which such corner record shall be presented and filed.

Figure 6-9 (Continued)
Corner Recordation Act

70-22-108. Corner records to be certified. No corner record shall be filed unless the same is signed by a registered surveyor and stamped with his seal, or in the case of an agency of the United States government or the state of Montana, the certificate may be signed by the survey party chief making the survey and approved, signed, and sealed by the registered surveyor in responsible charge of the agency.

70-22-109. Duties of county clerk. (1) The county clerk and recorder of the county containing the corner shall receive the completed corner record and preserve it in a hardbound book. The books shall be numbered in numerical order as filled.

(2) The clerk shall number the forms in numerical order as they are filed.

(3) The book and page number in which the corner record is filed shall be placed by the clerk near that same corner on a cross-index plat which the clerk shall provide for such purpose.

(4) The county clerk and recorder shall make these records available for public inspection during all usual office hours.

(5) There is no filing fee.

70-22-110. Surveyor to rehabilitate monument. In every case where a corner record of a public land survey corner is required to be filed under the provisions of this part, the surveyor must reconstruct or rehabilitate the monument of such corner and accessories to such corner so that the same shall be left by him in such physical condition that it remains as permanent a monument as is reasonably possible and so that the same may be reasonably expected to be located with facility at all times in the future.

Figure 6-10
Certified Corner Recordation Form

INSTRUCTIONS

1. Original and/or subsequent record used to evaluate the corner position.
2. Description of evidence found, note discrepancies in the record, state method of establishing lost or obliterated corners.
3. Description of monument and accessories set to perpetuate the corner position.
4. Sketch of corner, show all pertinent data which can best be shown in a sketch example, corner marking, topography ties, position of accessories, etc.
5. Certification must be signed and sealed by Land Surveyor registered in the State of Montana.
6. Fill in Cross Index & Section Diagram at bottom of sheet.

CERTIFIED CORNER RECORDATION

Corner _____ T. _____ R. _____ P.M.M. _____ County

CERTIFICATION

I, _____
certify the information shown hereon is true and correct.

_____
Signature Ground Party Chief

I, _____
certify that this Corner Record correctly represents work performed by me or under my direction in compliance with the "Corner Recordation Act" (70-22-101, et seq., M.C.A.)

_____
Signature of Surveyor & Seal

Date: _____ Reg. No. _____

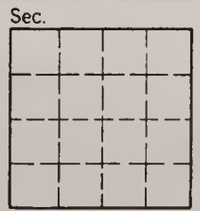
Employer: _____

SKETCH OF CORNER

Office of Clerk and Recorder, County of _____. This "corner record" was filed for record on _____ was noted on the cross-index plat and is assigned page No. _____, in book No. _____

_____
County Official

Sec.



• - corner this sheet

Cross Index No. _____ T. _____ R. _____ PMM

Adopted July 1, 1981, Montana Board of Professional Engineers & Land Surveyors

Figure 6-10 (Continued)
Certified Corner Recordation Form

INSTRUCTIONS TO SURVEYORS FOR COMPLETION OF CERTIFIED CORNER RECORDATION FORMS

I. ORIGINAL AND/OR SUBSEQUENT RECORD:

This item should describe or quote those portions of the original or subsequent record which were used in evaluating the corner position. The original record will usually be the General Land Office field notes. Subsequent record can come from several sources: Previously filed corner records, maps and plats, private and public records, etc. Some of the subsequent record, even though not in the public record, but known to have validity by the surveyor, may be quoted and appropriately noted.

The record data helps support the reestablished corner position because it clearly shows what history the surveyor based his corner position on. In some cases, however, the record may be unknown or not pertinent. A statement to that effect should appear on the corner record.

II. DESCRIPTION OF EVIDENCE FOUND OR METHOD OF LOCATING CORNER POSITION:

This item will describe the original or subsequent record evidence found. If portions of the found evidence cannot be reconciled with the record, then the disregarded record should be noted, and, if possible, an opinion as to its cause narrated.

If no physical evidence of the original or subsequent monuments and accessories can be found, then the method used to reestablish the lost or obliterated corner (single proportion, fence intersection, parol evidence, terrain calls, centerline of road, etc.) shall be indicated.

III. DESCRIPTION OF MONUMENTS AND ACCESSORIES SET TO PERPETUATE THE CORNER POSITION:

This item should list all details about the corner and its location which will help exclusively identify the corner position; including size and type of monument, how marked if not shown in sketch, and distinguishing topographic calls which help locate the corner. In many cases, instructions on how to find the corner should be included.

References or ties to other corners are optional and may be drawn on the face or back of the corner record form, or references to Certificate of Survey may be made. Separate drawings may be attached to the corner form.

If state plane coordinate values for the corner position are shown, then the control upon which they are based should be indicated.

IV. SKETCH OF CORNER:

This item will usually show how a found or set corner is marked and may also show topography or accessory monuments found or set and their relation to the corner. There is no stipulated format; the sketch could be transcribed field note entries.

V. CERTIFICATION:

The name and signature of the ground party chief is optional.

The Surveyor who performed or directed the field work which is depicted on the "Certified Corner Record" shall sign and affix his seal in the Certification.

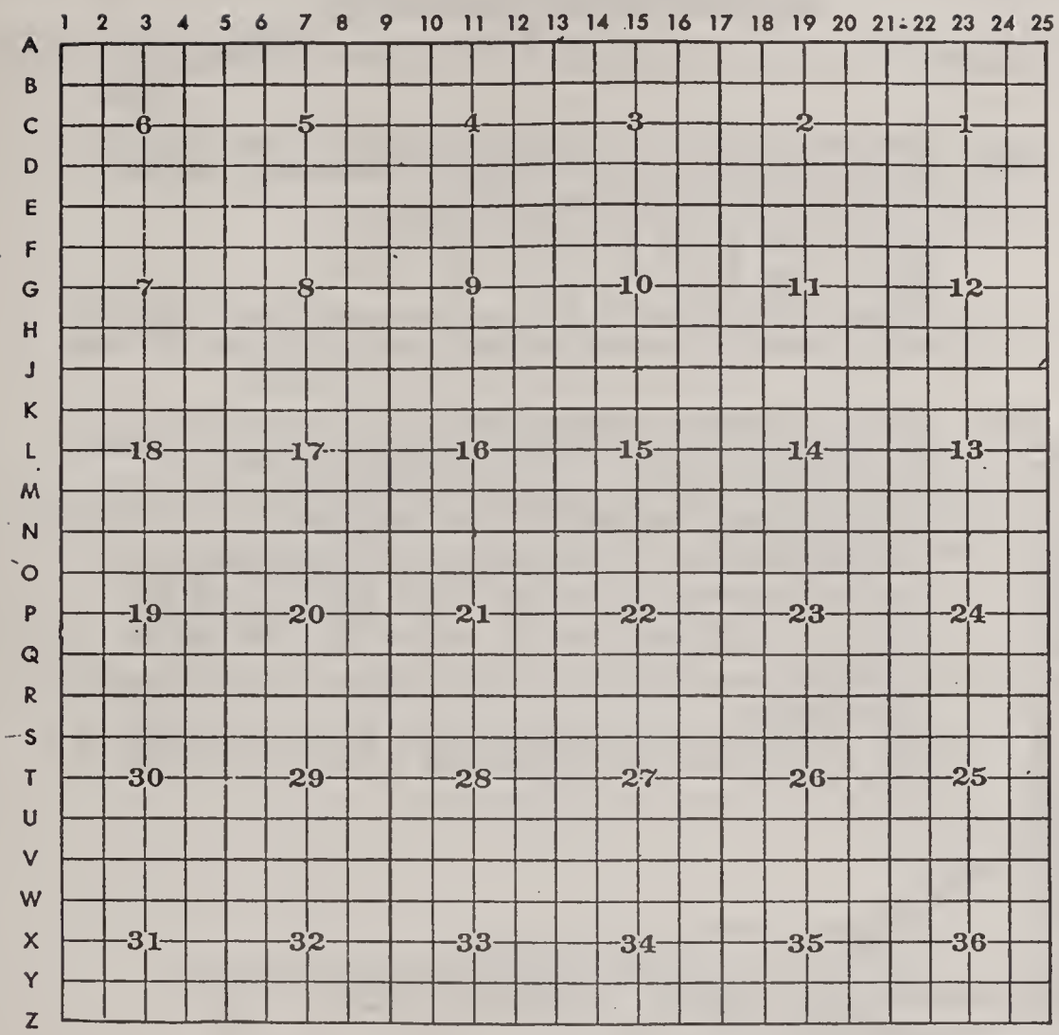
The employer blank is optional but useful in tracking down original field note data or adjacent record if, in the future, questions arise about the corner.

VI.

The Cross Index at the bottom of the page should be completed by the Surveyor. Only the single Township Index where the corner is filed shall be completed.

The lower righthand corner is a corner location diagram and should have the pertinent section filled in at the top and a closed circle indicating the appropriate corner position in the section filled in. This is intended to be an aid in searching the "Record" once it has been filed.

Figure 6-10 (Continued)
Index Diagram for Corner Recordations



LEGEND

Corners filed under this cross index plat.

Certificates filed in adjoining township as indicated by solid guandrant(s).

Each corner certificate is identified by an alphabetical-numerical coordinate number which is derived from the system shown on the township diagram. For example, the quarter-corner between Section 5 and 6 is identified as Corner C-5.

Corners such as meander corners or subdivision corners which are not located at intersecting lines on the above diagram will be identified by reference to the nearest applicable coordinate lines, thus:
AB-1; M-1-2; VW-19-20.

Corners common to adjoining townships will be identified by coordinates of the townships in which the certificates are to be filed.

Within each township record, the certificates will be filed in alphabetical-numerical sequence.

FORM 126—44762

T. ..... R..... .....MER.

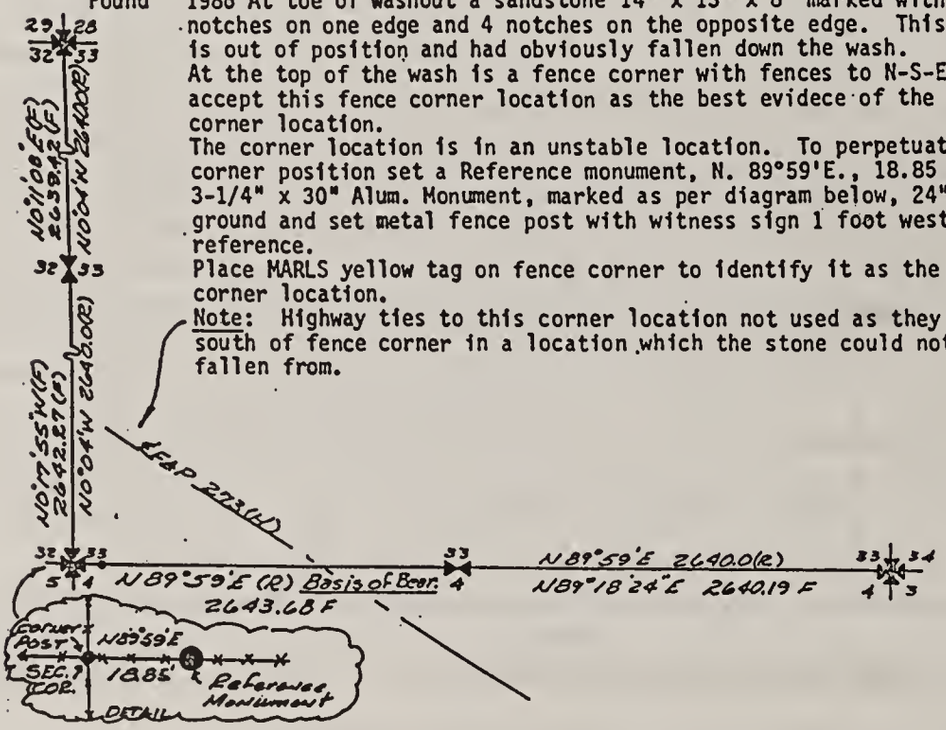
Figure 6-11
Certified Corner Recordation — Example 1

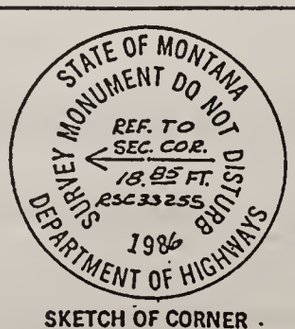
CERTIFIED CORNER RECORDATION

Corner 4, 5, 32 & 33 T. 2 & 26 N. 57 E. P.M.M. Richland County

Record 1908 (William B. Kimmel) Set a quartzite stone, 14 x 13 x 7 ins., in the ground for Cor. of sec. 4, 5, 32 and 33, marked with 4 notches on E. and 2 notches on W. edge, from which:
An ash, 14 ins. diam. bears N. 28° E. 150 Lks. dist.
Marked T. 26 N. R. 57 E. S 32 BT
An ash, 12 ins. diam. bears N 34° W., 65 Lks. dist.
Marked T. 26 N., R. 57 E., S 32 BT
No other trees within limits. Dig pits 18 x 18 x 12 ins. in Sec. 4 and 5, 5-1/2 ft. dist. and raise mound of earth 4 ft. base, 2 ft. high W. of Cor.

Found 1986 At toe of washout a sandstone 14" x 13" x 8" marked with 2 notches on one edge and 4 notches on the opposite edge. This monument is out of position and had obviously fallen down the wash.
At the top of the wash is a fence corner with fences to N-S-E-W. I accept this fence corner location as the best evidece of the original corner location.
The corner location is in an unstable location. To perpetuate the corner position set a Reference monument, N. 89°59'E., 18.85 feet, a 3-1/4" x 30" Alum. Monument, marked as per diagram below, 24" in ground and set metal fence post with witness sign 1 foot west of reference.
Place MARLS yellow tag on fence corner to identify it as the section corner location.
Note: Highway ties to this corner location not used as they fell 22' south of fence corner in a location which the stone could not have fallen from.





SKETCH OF CORNER

Robert R. Kuster RATIFICATION

I, _____ certify the information shown hereon is true and correct.

Robert E. Kuster 7/22/86
Signature Date

I, _____ certify that this Corner Record correctly represents work performed by me or under my direction in compliance with the "Corner Recordation Act" 70-22-101, et seq. M.C.A.

ROBERT S. TWEETEN 3255
Signature of Surveyor Reg. No.

Date: 7/16/86 MDOH
Employer: MDOH

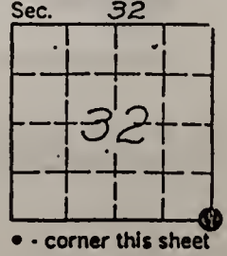
REGISTERED LAND SURVEYOR

Office of Clerk and Recorder, County of _____. This "corner record" was filed for record on _____ was noted on the cross-index plat and is assigned page No. _____, in book No. _____

_____
County Official

RSC:kw:1ff/3

Sec. 32



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Cross Index No. Z-9 T. 26N R. 57E PMM

Adopted July 1, 1981, Montana Board of Professional Engineers & Land Surveyors

Figure 6-12
Certified Corner Recordation — Example 2

CERTIFIED CORNER RECORDATION

Corner West 1/4 Cor. Sec. 29 T. 29 N. R. 6 E. P.M.M. Liberty County

RECORD

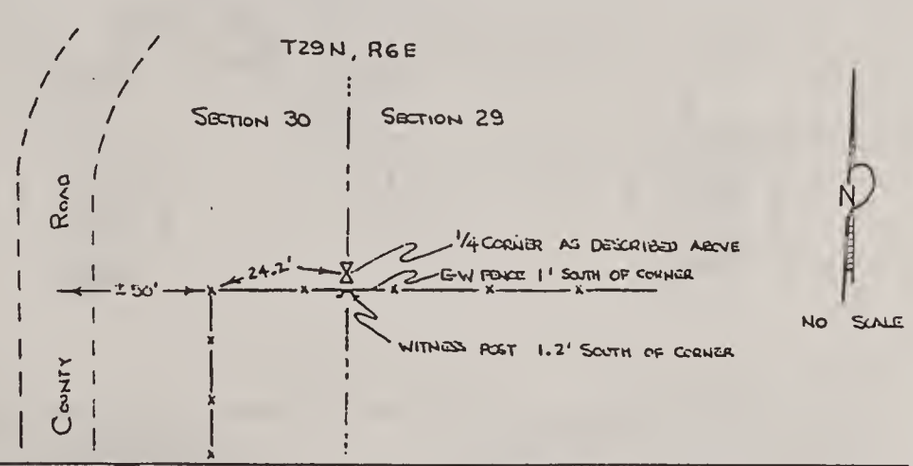
1896 G.L.O. survey notes of the subdivisions of T29N, R6E by Joseph H. Heyer.

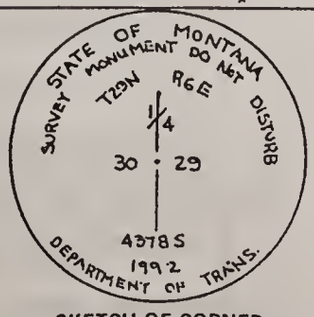
40.00 Set a lime stone, 17x9x8 ins. 12 ins. in the ground, for 1/4 Sec. Cor., marked 1/4 on W face; dig pits, 18x18x12 ins. N and S of stone 3 ft. dist.; and raise a mound of earth 3 1/2 ft. base, 1 1/2 ft. high, W of Cor.

1992

Found 18"x10"x6" stone firmly set and clearly marked 1/4 on the west face. No evidence of the pits was apparent. Markings not mentioned in the G.L.O. record were found on the base of the stone and appeared to be either JA or JH.

At the corner position, set a 2 1/2"x30" aluminum post with a 3 1/4" aluminum cap marked as indicated on the diagram below, 25" in the ground. Set a 5/8"x24" rebar inside the aluminum post for a subsurface mark, bury the found stone upside down along the north side of the aluminum post, set a metal fence post with witness decal 1.2 feet south of the corner, raise a collar of stone around the aluminum monument and make accessory ties as indicated in the sketch.





SKETCH OF CORNER

CERTIFICATION

I, Bryce Larsen certify the information shown herein is true and correct.

Signature Ground Party Chief

David R. Davis

I, David R. Davis, certify that this Corner Record correctly represents work performed by me or under my direction in compliance with the "Corner Recordation Act" (70-22-101 et seq. M.C.A.)

Signature of Surveyor & Seal

MONTANA DAVID R. DAVIS #4378S REGISTERED LAND SURVEYOR

Date: 4/1/92 Reg. No. 4378S

Employer: MDT

Office of Clerk and Recorder, County of _____. This "corner record" was filed for record on _____ was noted on the cross-index plat and is assigned page No. _____, in book No. _____

_____
County Official

Sec. 29

• · corner this sheet

Cross Index No. T-5 T. T26N R. R6E PMM

DD:Q:BR:PS:13.dr/3

Adopted July 1, 1981, Montana Board of Professional Engineers & Land Surveyors

Figure 6-13
Certified Corner Recordation — Example 3

CERTIFIED CORNER RECORDATION

Corner Northwest Corner, Section 35 T. 21 N. R. 48 E. P.M.M. McCone County

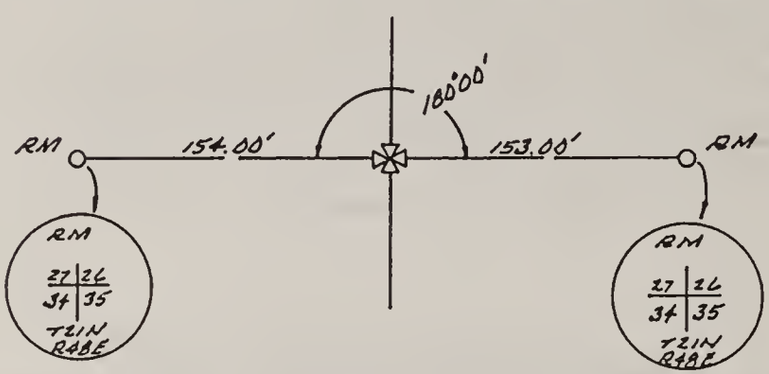
1. Set a sandstone, 14x12x10 inches 9 inches in the ground, for Corner of Sections 26, 27, 34, and 35, marked with 1 notch on South and 2 notches on East edges; dig pits 18x18x12 inches in each Section, 5½ feet distance, and raise a mound of earth, 4 foot base, 2 feet high, West of Corner.

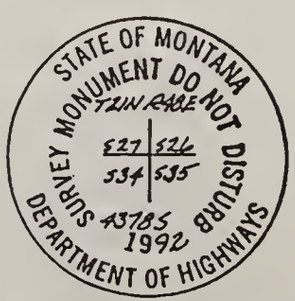
2. 1988 - Found Montana Department of Transportation rebar and aluminum cap at the Corner location.

3. 1988 - Set a 30" x 2½" Montana Department of Transportation aluminum monument for the corner location at the same spot as the existing MDT rebar and cap were located.

4. 1991 - Prior to road construction on State Highway #13, a Montana Department of Transportation survey crew found a MDT aluminum monument and set two 5/8" x 30" rebar with 2" aluminum cap reference monuments as shown below.

5. 1992 - After road construction, set a 30" x 3¼" Montana Department of Transportation aluminum monument 1 inch below paved road surface, stamped as shown below, at the Corner location which is 1.66 feet East of the centerline of State Highway #13. (Project STPP 25-1(18)17.)





SKETCH OF CORNER

CERTIFICATION

I, Randal R. Pisk
certify the information shown herein is true and correct.

Signature Ground Party Chief

I, David R. Davis
certify that this Corner Record correctly represents work performed by me or under my direction in compliance with the "Corner Recordation Act" (70-22-101, et seq. M.C.A.)

Signature of Surveyor & Seal

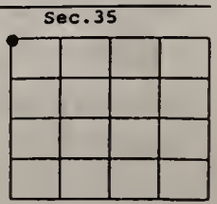
Date, 5/92 Reg. No. 4378S

Employer: MDT

Office of Clerk and Recorder, County of _____. This "corner record" was filed for record on _____ was noted on the cross-index plat and is assigned page No. _____, in book No. _____

_____
County Official

Sec.35



Cross Index No. V-17 T. 21 N. R. 48 E. PMM

● - Corner this sheet

DD:BL:Q:PS:2.dr

Adopted July 1, 1981, Montana Board of Professional Engineers & Land Surveyors

Figure 6-14
Certified Corner Recordation — Example 4

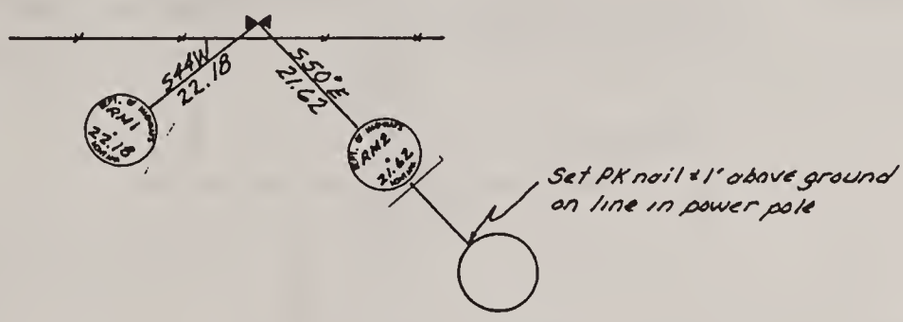
CERTIFIED CORNER RECORDATION

Corner ¼ Corner 8 & 17 T. 15 N. R. 16 E. P.M.M. Fergus County

Record - GLO 1875 - Set a limestone 18x10x6 inches 10 inches in the ground, marked ¼" on north face. Dug pits 18 inches square, 12 inches deep; N., S., E., and W. 5½ feet distant.

Found - 1992 - Record stone, firmly set, as described above, 2 feet north of an east/west fence line. No evidence of pits.

Set - 1992 - At the found position of the record stone I set a 3½"x30" aluminum monument, stamped as shown below, 24" in the ground and raised a mound of rocks around the aluminum cap. I buried the record stone. A steel witness post with decal was set 1' west. Two RMs were set as shown below.



STATE OF MONTANA SURVEY MONUMENT DO NOT DISTURB T15N R16E 8 & 17 ¼ 4378S 1992 DEPARTMENT OF TRANS.

SKETCH OF CORNER

CERTIFICATION

I, John Huber certify the information shown herein is true and correct.

Signature Ground Party Chief

I, David R. Davis certify that this Corner Record correctly represents work performed by me or under my direction in compliance with the "Corner Recordation Act" (70-22-101, et seq., M.C.A.)

Signature of Surveyor & Seal

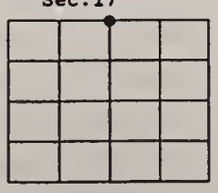
Date: 8-92 Reg. No. 4378S

Employer: MDT

Office of Clerk and Recorder, County of _____. This "corner record" was filed for record on _____ was noted on the cross-index plat and is assigned page No. _____, in book No. _____

_____
County Official

Sec. 17



Cross Index No. J7 T. 15 N. R. 16 E. PMM

● - Corner this sheet

DD:BL:Q:PS:5.dr/162

Adopted July 1, 1981, Montana Board of Professional Engineers & Land Surveyors

Figure 6-15
Certified Corner Recordation — Example 5

CERTIFIED CORNER RECORDATION

Corner 16, 17, 20 & 21 T. 1S R. 54E P.M.M. Powder River County

Record - 1890 - Set a sandstone 18x12x3 inches, 12 inches in the ground. Marked 3 notches on the south, and 4 notches on the east. Dug pits 18x18x12 inches in each section, 5½ feet from stone. Raised a mound of earth 2 feet high, 4½ foot base alongside.

Record - 1940 - Found stone firmly set and marked as described above. Removed the stone and put in its place a 3 foot long, 2 inches in diameter, iron post set 30 inches in the ground with a brass cap marked.

Pits impractical

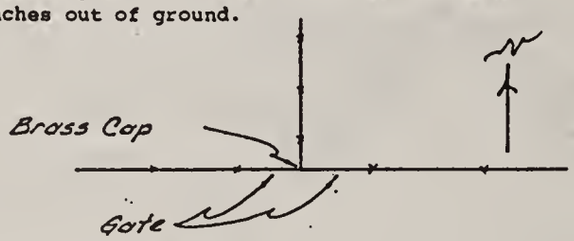
T1S R54E

S17	S16
S20	S21

1940

Found - 1992 - Found 2 inches in diameter iron post, with 2½ inch brass cap stamped as shown below. Cap is 3 inches above ground. Cap is at a fence corner, with gates east and west. Also found a sandstone 3x12x3 inches protruding from ground. Left as it is directly alongside the cap. No visible markings on stone.

Set 1992 - Steel U post with decal 21 inches northeast of cap. Post is 4 feet 4 inches out of ground.



U.S. GENERAL LAND OFFICE SURVEY
FOR REMOVAL $250
T1S R54E
S17 | S16
S20 | S21
1940

SKETCH OF CORNER

CERTIFICATION

I, Douglas J. Martin, certify the information shown hereon is true and to...

Signature Ground Party Chief

I, David R. Davis, certify that this Corner Record correctly represents work performed by me or under my direction in compliance with the "Corner Recordation Act" (70-22-101 et seq. M.C.A.)

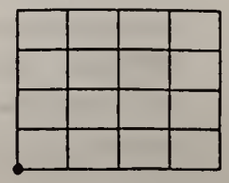
MONTANA REGISTERED LAND SURVEYOR DAVID R. DAVIS 4378-S

Signature of Surveyor & Seal

Date: 8/92 Reg. No. 4378S

Employer: MDT

Sec.16



Office of Clerk and Recorder, County of _____. This "corner record" was filed for record on _____ was noted on the cross-index plat and is assigned page No. _____, in book No. _____

_____
County Official

Cross Index No. N9 T. 1S R. 54E PMM

● - Corner this sheet

DD:BL:Q:PS:6.dr/57&58 Adopted July 1, 1981, Montana Board of Professional Engineers & Land Surveyors

Figure 6-16
Certified Corner Recordation — Example 6

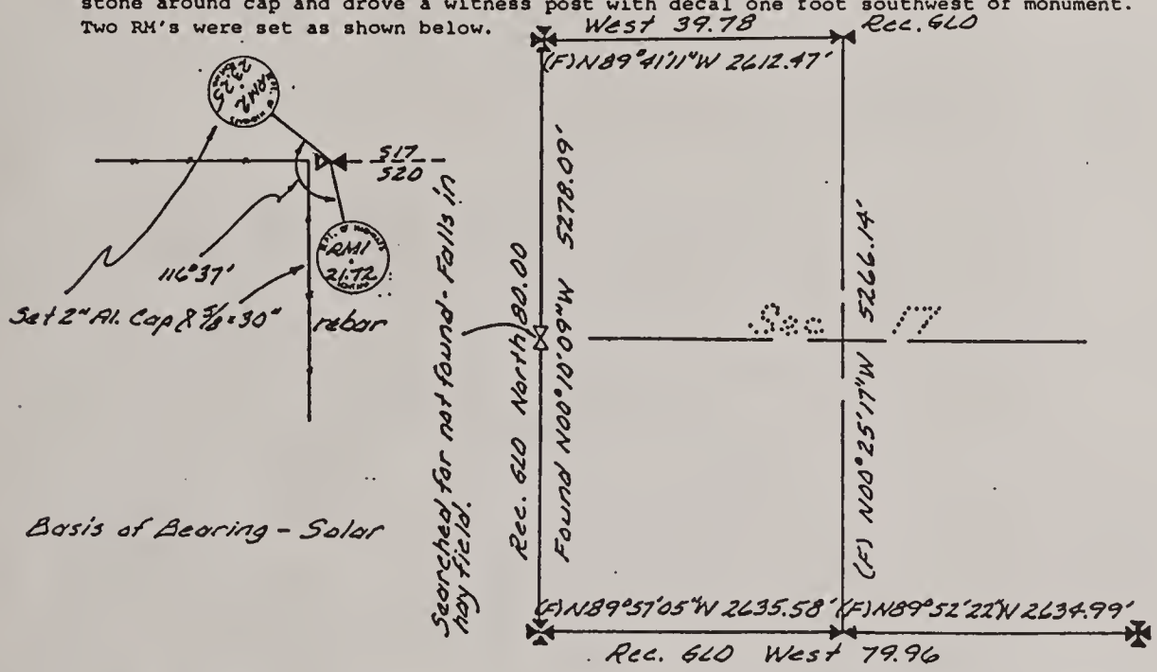
CERTIFIED CORNER RECORDATION

Corner 1/4 Corner 17 & 20 T. 15 N. R. 16 E. P.M.M. Fergus County

Record - GLO 1875 - Set a limestone 14X8X6 inches 8 inches in the ground,marked 1/4 on north fact. Dug pits 18 inches square, 12 inches deep N.,S.,E., and W. 5½ feet distant.

Found - 1992 - No evidence of original stone or pits. I accept an existing fence corner as the nearest and best evidence as to the original position.

Set - 1992 - 6 inches east of the existing fence corner. I set a 2½ inch X 30 inch flared aluminum monument having a 3¼ inch cap marked as per diagram below 29 inches in the ground. An electric (glass) insulator was buried alongside the aluminum cap. A 5/8 X 30 inch rebar was placed inside the flared aluminum monument. Raised a mound of stone around cap and drove a witness post with decal one foot southwest of monument. Two RM's were set as shown below.



SKETCH OF CORNER

STATE OF MONTANA SURVEY MONUMENT DO NOT DISTURB
T15N R16E
S17
S20
4378S
1992
DEPARTMENT OF TRANS.

CERTIFICATION

I, John Huber
certify the information shown herein is true and correct.

Signature Ground Party Chief

I, David R. Davis
certify that this Corner Record correctly represents work performed by me or under my direction in compliance with the "Corner Recordation Act" (70-22-101, et seq., M.C.A.)

Signature of Surveyor & Seal

Date: 8-92 Reg. No. 4378S

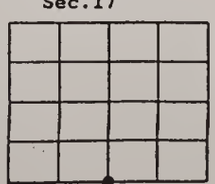
Employer: MDT

Office of Clerk and Recorder, County of _____. This "corner record" was filed for record on _____ was noted on the cross-index plat and is assigned page No. _____, in book No. _____

_____
County Official

Cross Index No. N7 T. 15 N. R. 16 E. PMM

Sec.17



● - Corner this sheet

DD:Q:PS:8.cg

Adopted July 1, 1981, Montana Board of Professional Engineers & Land Surveyors

Figure 6-17
Certified Corner Recordation — Example 7

CERTIFIED CORNER RECORDATION

Corner 28|27 / 33|34 T. 15 N. R. 13 W. P.M.M. Powell County

GLO RECORD (1873): 15 x 8 x 7 ins. sandstane.

RECORD "RAINBOW VALLEY" subdivision plat by R.J. Hale (1959): This section corner is shown as the Northwest corner af "Rainbow Valley" hawever, there is no mention of what monument was faund by the surveyar at that time.

FOUND - 1991: .....a marked stone af roughly the original dimensions lying loose on the surface. A substantial area surrounding the position of the found stone has been disturbed by some sart of excavotion and/or grading, perhaps 15 or 20 yeors ago.

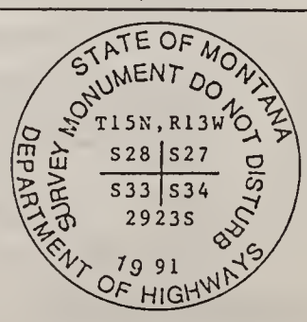
As there is no evidence to determine where this loose stone was originally set, some assumptions were made. Although he does not state what he found ot the position of this section corner, one can assume that Hale found something here when he was doing the survey of "Rainbow Valley" in 1959. Assuming this area was not disturbed in 1959, Hale "probably" found the original stone, set in its original position, which would make the lot corner monuments set by Hale in the "Rainbow Valley" subdivision "reference" monuments ta the original section corner stone and, the best evidence available for re-establishment of this section corner position.

An analysis of the "Rainbaw Valley" subdivision disclased the following: The perimeter boundary and accompanying legal description was found ta close fairly well (plus/minus 1 ft.) hawever, the interior baundaries were found to have multiple errars. Ties to numerous original lot corner stones throughout the subdivision indicate that the errors were made along the northeasterly boundary of lots 9 - 16. It appears the errors on the plat were monumented on the ground as well.

The position for this corner wos computed from record ties shown on the "Rainbow Valley" plot, disregarding the portion of the plat record, ond found monuments olong the northeosterly interior boundory of lots 9 - 16 where the errors oppear to hove been mode. The section corner was positioned using o Least Squares "best fit" odjustment of the record "Roinbow Valley" plot to the remoining monumented lot corners os found on the ground, which fit the plot foirly well.

SET - 1991: At this computed position, we set o 2-1/2" x 30" aluminum pipe with o standard MDOH 3-1/4" aluminum cap, 29" in the ground and marked as noted below. We buried the original stane along side and placed a steel post with "MARLS" tag alang side the monument. There are no reference objects within a reasonable distance of corner. This computed and monumented position falls in Northerly end of the disturbed area, same 65 feet Narth of the position where the original stone was faund loose, at the Southerly end of the disturbed area. Monumented position fits the GLO terrain call ta the river to the South within about 9 feet ond falls about 104 feet Eost of the centerline of the Scotty Brown Road.

SEE CERTIFICATE OF SURVEY NO. 400



SKETCH OF CORNER

CERTIFICATION

I, Ken E. Jenkins, PLS

certify the information shown herein is true and correct.

Signature Ground Party Chief

I, R.A. Ainsworth

certify that this Corner Record correctly represents work performed by me or under my direction in compliance with the "Corner Recordation Act" (70-[illegible])

Signature of Surveyor

Date: June 1991 23rd No. 2923S

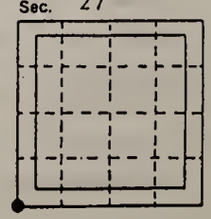
Employer: PROFESSIONAL CONSULTANTS, IN

Office of Clerk and Recorder, County of Powell. This "corner record" was filed for record on the ____ day of _____ 19____, was noted on the cross-index plat and is assigned page No. _____, in book No. _____

County Official

Cross Index No. V-13 T. 15N R. 13W PMM

Sec. 27



Data Collector

Insert as reference only in Survey Manual - Chapter 8

Practical Help Guide

Part 1: Data Collector Use & Technique
Part 2: Editing the Data
Part 3: Survey Viewer
Part 4: The Jagoda Papers
Contact Persons....inside front cover.

O:\SAFTEY\TIM\DATCOL.WPD

November 1998

FOR DISTRICT ASSISTANCE: PRIMARY CONTACTS

1. Missoula District	*Tom Benedick **	*523-5864*	*Data Collector, Survey*
	Terry McDonald	*523-5820*	*Computers, Connecting*
Kalispell	*Mark Roedel*	*755-8559*	*Data Collector, Survey*
	*Ed Toavs**	*257-3395*	*Data Collector, Survey*
2. Butte District	*Paul Jagoda **	*285-4732*	*Data Collector, Survey*
	Bill Fogarty	*782-9327*	*Data Collector, Survey*
	Dan Zahn	*494-9621*	*Computers, Connecting*
3. Great Falls District	*Beth Scofield*	*265-6821*	*Data Collector, Survey*
	Levi Doll	*265-6821*	*Data Collector, Survey*
	*Mike Ostertag **	*454-5921*	*Data Collector, Survey*
	Gary Brandt	*454-5911*	*Computers, Connecting*
4. Glendive District	*Danny Hood **	*365-2877*	*Data Collector, Survey*
	Dale Boehning	*365-5296*	*Computers, Connecting*
5. Billings District	*Gerry Brown **	*538-8732*	*Data Collector, Survey*
	Jack Carlson	*245-9820*	*Computers, Connecting*

If there are problems, District personnel should contact the above people. If the primary contact person(*) is unavailable or unable to answer questions, they will contact Photogrammetry & Survey or Joe Reed

Secondary contacts:

1. Dave Davis *Photogrammetry/ Survey-Helena 444-7609 or 444-6020.*

a. The primary contact should request assistance. Information is then relayed to others.

2. Joe Reed
MapVision Systems,Inc.
Round Rock, TX
1-888-249-2598 toll free

3. Tim Boucher *Viewer*
406 444-7269

Data Collector

Insert as reference only in Survey Manual - Chapter 8

Practical Help Guide

Part 1: Data Collector Use & Technique
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Part 3: Survey Viewer
Part 4: The Jagoda Papers
Contact Persons....inside front cover.

O:\SAFTEY\TIM\DATCOL.WPD

November 1998

Table of Contents i

For Assistance: Primary Contacts inside front cover

Part 1: 1

MDT Micropalm Data Collection User Outline 2

Overview of the Data Collection System 2

Control Traverse 3
- Layout 3
- Configure the Total Station 3
- Configure the Data Collector 3

Begin Actual Traverse 7

Double-ties to Property Controlling Corners 11
- Configure the Total Station 11
- Configure the Data Collector 11
- Choices You Make 11
- Max Set Error 11
- Scale Factor 11
- Begin Shooting 11
- 2-Set Sideshoots 12

Topography 15
- Configure the Total Station 15
- Configure the Data Collector 15
- Begin New Job or Continue Existing Job 15
- Data Collector - Ready to Begin 17

Feature Code List 20

Feature Codes 21

File Management 23

File Names 25

Monumentation 26

Summary 27

Part 2: 29

Editing the Data 30

Files 31
Types and Extension Names 31
Editing 32
Editing the .RAW File 33
After Processing 34
Repeat Processing with Edited .RAW File 34
Editing Coordinates in the .CRD File 35
Final Edit Procedure with Designer 36
Storing and Submitting Files
Control Files 37
Project Survey Files 37
Things to Remember 38

General Comments to Accompany Data Collector Flow Chart 40
Control Traverse Is Required 40
Bench Levels 41
Tie to Section corners, R/W Monuments & Property Corners 42

For Assistance: Primary Contacts 43

Part 3: 45

MDT Survey Data Viewer 46

Introduction 47
Startup Form 47

Main Form File Menu 48

Startup Form File Dropdown Menu Items 48
View Design File Options 49
View Display 50
File Menu 51
Display Menu:
Levels 52
Element Types 54
View Attributes 55
View 56
Utility Menu:
Text Search 57
Analyze 58
Working Units 58
Get Global Origins 59
Cells 59
Options 60
User Options 60
View Import Messages 61
Help 62
Contents 62
About MDT Survey Data Viewer 1.1 Beta 62

Menu Map for Survey Viewer 63

Part 4: 65

The Jagoda Papers 65

Data Collector Training 66

File Management Setup 66
Data Collector Setup 68
Collecting Data 69
Downloading From Data Collector to Computer 70
Processing Data 71
Editing Data 72
Creating .FLD Design File with the Viewer 74
Data Transfer to the DI Subdirectory 76
Data Collector Tips 77
PC/Laptop Tips 79
Viewer Tips 81
To Calculate Figures 82
Calculating Radius Point Coordinates 84
Data Collector for Stockpiles 85
To Print CRD List from Survey Office 88

Helpful Handouts 91

READ ME FIRST - Litium Battery & Formating 92
Sign Cell Libraries 93
Sample Memo to DCE & DI Directory 109
Sample read.me File 110
Updating Data Collector Software 111
Daily Data Collection Form Sample 115
Another Daily Data Collection Form Sample 117
New Baseline User Report 119
Docking Station Info 120
Battery Info 121
New Survey Protocol 122
File Editing Information 125
Preliminary Survey Request Form 127

Part 1:

MDT Micropalm Data Collection User Outline

Craig Brown, P.L.S.
Montana Department of Transportation
Right-of-Way Bureau
2701 Prospect Avenue
P.O. Box 2011001
Helena, MT 59620
Phone: (406) 444-7683
e-mail: crbrown@state.mt.us

MONTANA DEPARTMENT OF TRANSPORTATION
MICROPALM DATA COLLECTION
USER OUTLINE
version 1.0

OVERVIEW OF THE DATA COLLECTION SYSTEM

The department has adopted the Micropalm data collector as a system for the collection and storage of field survey data. With the introduction of CADD capabilities within the department, came the necessity for rapid and reliable methods of collecting, storing, and transferring data from the field to the office CADD network.

Survey data is collected directly from the total station and stored in an MS-DOS file directory on a hard drive similar to the PC. The program prompts the user for the data needed to complete the desired task. Hand-measured values such as instrument heights and target heights are entered into the collector to be stored in the .RAW file along with angles and distances measured by the total station. Point descriptions, feature codes, and comments are also entered and stored in this file.

The basic function of the data collector is to replace the written field book and eliminate some human errors such as transposing numbers and failing to record necessary data. The collector is set up to collect all raw measurements from the total station with a minimum of keystrokes by the user.

Survey procedures from the Survey Manual are still to be followed as the standards for the department. Good field practices are still essential for the accurate and efficient gathering of data.

We'll go through the steps of each type of survey and show a recommended procedure for getting started. The following is only recommendations as each survey will be a little different based on personnel, terrain, scope of work, etc. Use the method that works for you and that you are most confident using. The goal is to transform the existing terrain into coordinates and give the designer an accurate, usable product with the fewest trips to the field.

CONTROL TRAVERSE

1. Layout

a. Set the appropriate monumentation at strategic locations outside of the estimated construction limits along the project. All traverse points should be in place before the control traverse is started. This will save unseen problems down the line. Make sure points are intervisible and in places where you can use them for future topo and pickup surveys. Any problem areas can be identified and a control point set nearby.

b. Descriptions (Abstract) are to be recorded in field books.

2. Configure the Total Station

a. After setting the instrument over the first traverse point, be sure to measure and enter the PPM (Parts Per Million) in the instrument.

b. Make sure your instrument is set to the proper units (Feet or Meters).

3. Configure the Data Collector

a. At the DOS prompt **(C:\)** type **SF**, and Enter--this will activate the field survey program.

b. From the first menu, highlight **Data Collection and COGO** and Enter.

c. Next select **Select Instrument**

d. Choose the instrument you will be using for the traverse

1. If **Topcon**, select it. Our model is the **GTS 4A**
   You probably want **Fine Measurement Mode** and choose **No CR/LF(Default)**.
   This will take you back to the **Main Menu**.
2. If **Leitz(Sokkia)**, select that and then select **B Series** and **Fine Meas. Mode**
   This should be all you need to select for this instrument.

You should now be back at the Main Menu

e. If this is a new traverse, select **Begin New Job**, this will prompt you for a new .**RAW** filename. You can have only **one** traverse in a .**RAW** file. If your project will have more than one traverse loop, you will need a new .**RAW** file for each. Compass and Crandall Rules will handle only one loop adjustment at a time.

1. If you are continuing a traverse select **Continue Existing Job**. This will allow you to start at the end of a previous .**RAW** file and continue collecting data.

Remember: If you're using the same .RAW filename, Begin New Job will overwrite the first one. Continue Existing Job will append to the first one.

f. Next is **File Entry**--

1. Name the .**RAW** file to be used, e.g., 2222TR01.RAW
2. Name the .**CRD** file to be used. This can be one you have already used containing the coordinates to calculate your traverse. You can push **F2** to see all the .**CRD** files in this directory to choose from. If you want a new .**CRD** file created, you can do that here. It will ask you to select the measurement units (**F** or **M**).

This file is one you really need to keep track of. It can be reproduced very easily but the coordinate values in this file will determine how the rest of your survey is processed. When you want to load coordinates into the data collector, this is the file they will go into. For instance, you've done your survey with assumed coordinates and elevations and you want to process with the correct values. You would load the good coordinates into the .**CRD** file with the SurVis software. This file is binary and will not allow any duplicate point numbers or names. Anytime you try to enter a point name that is already in the **.CRD** file, a warning will appear giving you the option of overwriting the point or not.

3. You can choose a .**FIG** file here. If you aren't collecting **FIGURES**, then this file is not important and will default to the same filename as the .**RAW** file. **FIGURES** can be discussed at another time. You won't need to collect figures during the traverse unless you're wanting to calculate the area, then you need to assign a **FIGURE** No. We'll discuss this later.

4. Choose **PCODES.FF** for the .**FF** file. This is the only one we are using at this time and contains all the feature codes. During the traverse, **TRAV** is probably the only feature code you'll use.

5. If all your file selections are correct, then type **Y** at the **Continue?** prompt.

All field data collected will be stored in the .RAW file, all occupied point, backsight point, and
foresight point coordinates (XYZ) will be stored in the .CRD file, figures in the .FIG file, and so on

The next screen is the *Project Info* board.

This screen is information about the project. Fill in as much of the entries as you can. It's a good idea to at least fill in the **Control Number, Project Number and Project Name**. Also, you can give information about what this particular phase of the job is, e.g., TRAVERSE FROM 1A TO 3Z , TOPO BRIDGE AREA, or UTILITY LOCATION, whatever. Fill in the crew members. You can fill in the **Temperature, Pressure, and PPM**, but this is for information only.

These values need to be **set in the Total Station**. The data collector does not communicate this to the instrument.

Important: **Units [F or M]**

Here is where you will set the units of measurement for the project. Once you have entered a point into that .CRD file as Feet or Meters, the units cannot be changed. If you make a mistake and enter the wrong unit, either start a new .CRD file or delete the old one and start over at the file selection screen.

If everything looks OK, say *Y* at *Continue?*, and Enter.

****

You are now ready to start the Traverse.

After the Project Info screen is accepted, another screen appears showing the name of the current **.CRD** file and how many points are contained in it. If you are beginning a new traverse and are using a new **.CRD** file, there will be **No points entered**.

You should now be at the* TRAV *menu

To begin the traverse you must tell the data collector what you want to do.

Go to **Preferences**

For the Control Traverse you will want **4 Direction Sets,** Put a **Y** in the **[ ].**
You can change the **N** to a **Y** by pressing the **space bar** or type it in.
Set the **Max. Set Error** at **5.000 seconds,** according to the Survey Manual.
If you are using State Plane Coordinates, enter the **Scale Factor** here, e.g., 0.99964534,
If not State Plane Coords, leave this at 1.0000000.
Set **EDM in Fine Mode** to **[Y]**

Everything else in this screen can be left at the default settings, but you should familiarize yourself with their functions. Save it with a **Y** in the **[ ].**

Next select **Auto Traverse**

This will give you a **Start New Traverse** screen.

At **Backsight Point,** enter the name of the backsight point, e.g., 54A, 301Z, whatever.

If you know the coordinates and elevation of the backsight, enter them here. If this information is already in the **.CRD** file, the coordinates will display. If you don't know them, leave it blank.

At **Occupied Point**, enter the name of the occupied point.

Enter the coordinates and elevation of the occupied point.

If you don't know the coordinates or elevation of either the backsight or the occupied point, you will have to use assumed information in order to begin the survey. The real coordinates can be entered during processing at a later date.

If the coordinates are known and entered into the data collector, the **bearing** will be calculated and displayed in the field- **Enter a Bearing**. If you know the bearing from the occupied point to the backsight, enter it, or enter an assumed bearing. Pick something that is easily recognizable as being assumed like S0°00'00"E or N90°W.

Important: If you are assuming coordinates, go into Coordinate Geometry and calculate coordinates of your beginning points. Then start the Traverse by occupying the down line traverse point and backsighting the other one. This helps in processing.

At the **Inst. Height** field, Enter the measured height of the instrument to the nearest hundredth for F or to the nearest millimeter for Meters.

Even though the coordinates and elevations are assumed, you can collect the raw field data necessary to begin, close, and calculate a traverse.

If all the entries are correct, Save it with *Y* and continue.

****

After entering and accepting the Occupied and Backsight points, the next screen is the* Feature Codes *and* Descriptions *of those points. Most likely, the feature codes for the traverse points will be* TRAV. *You can enter what you want in there but* TRAV *is probably the one you want. You can enter a* Group No. *if you want the traverse lines to be drawn in the graphics. At* Descriptor, *you can describe what these points are monumented with, e.g., 51mm AC at MP 50, 20m RT, whatever.

***You can* Select a Figure *if you want to calculate the area of the traverse or have some other use for the legs of the traverse itself. Otherwise, leave this field at* N.**

If everything is correct, **Save it [Y]**, and continue.

Begin Actual Traverse

At this point, you should be at a screen prompting you to take a backsight.

The top of the data collector screen should read:

AUTO TRAVERSE BS ? OCC ?

Your **backsight point** and **occupied point** should be displayed here. If not, you need to enter the right ones.

You will be turning 4 Position angles for the Traverse. Use **0°, 45°, 90°,** and **135°**for the **BS** values.

If your instrument is ready with the PPM's set and the horizontal circle set to **0°**(preferred), the data collector is prompting you to **Backsight Direct 0°.**

Press **Enter** at the highlighted **Collect Angles and Distance.**

This will prompt the Total Station to take a shot at the Backsight target.

The prompt will then read: **Foresight Direct,** turn to the first traverse point. When centered on the target, highlight **Collect Angles and Distance** and press **Enter.**

Next **Foresight Reverse, Collect Angles and Distance, Enter**

Then finish the set with **Backsight Reverse**, **Collect Angles and Distance,** and **Enter**

The following screen will then give the results of the first set of angles, based on one set only.

You will now be prompted to take the next set of angles with **45°** as the **Backsight value.**

Follow the same procedure for the completion of the second set. The comparison at the end of the second set will have 2 sets to compare for tolerance.

Continue to shoot sets 3 and 4 using **90°** and **135°** as the backsight values. At the end of the 4th set, you can see the results of the 4 positions. All 4 sets are displayed and you can choose any of the sets to be returned if necessary. It will ask you if you're **Finished Shootng Sets?** If so, press **Y,** for Yes. If No, choose the number of the set (1,2,3 or 4) that you would like to re-turn, with the appropriate backsight value. Repeat this step until tolerances are reached.

Next the **foresight information** needs to be entered.

At the top of the board, the mean results of the foresight shot are displayed; **H Ang., V Ang., Slope Dist., and Hor. Dist.**

You can look at the ***unadjusted*** coordinates of the **foresight** point if desired at the first cursor location. Press **Enter** at the **[Y]**.

Enter **BS Targ Height** at the prompt.

Enter or check the **Inst. Height.** It should still be there from the other screen.

Enter the name of the **Foresight Pnt,** --58A, 65B, whatever

Enter the **Target Height** of the ***foresight*** point

Enter the **Feature Code**--probably TRAV

Enter a **Group Number** if you want the Traverse lines drawn, if not, leave it blank.

Give the traverse point a **Description,** e.g., 51mm AC at MP 30, whatever

Save it and Continue--

You're now finished with this leg of the traverse.

****

Continue by repeating these steps at each traverse point . Shoot the entire traverse, including shooting to a known point and measuring a closing angle to another known point to close the bearing.

IMPORTANT: ****READ THIS AND UNDERSTAND****

When shooting to the known points, you must give them a different point ID. Known Points are points that already exist in the .CRD file.(XYZ coordinates). When shooting the first loop, you may only have one Known Point and a Direction to the initial backsight. If this is the case, the beginning occupied point is the only one in the .CRD file that you need to rename when closing. In any subsequent loops, where you are using 2 points from a previous traverse to begin and close on, you will need to rename those points when you traverse through them.

In the closure menu, any points that are not to be included in the adjustment must be given their true names (Known Occ.Pnt and Known Pnt @ Inst.). **Example:** *Control coordinates from a GPS survey, when used as Occupied point, Backsight point, or Closure points, must be given their true names. Do not give these points their true names if they are being shot as Foresights.*
Also, any points that you do not want overwritten, you must give them a different point name.
Example--*call 58A,* **58AA,** *call 605,* **605A,** *whatever, just so it's something different.*

When all the data is collected, it is time to End the traverse.
From the **TRAV** menu, go to **End Auto Traverse**, the TRAVERSE CLOSURE screen will display.
If you are using assumed coordinates, where all points are being included in the adjustment, use the default entries. The Known Pnt @ Inst. field will be blank, the Known Pnt @ FS should be the point you are turning your closing angle to.

If using more than one known point to close on:
Enter the **Actual ID** at the prompt **Known Pnt @ Inst.**
Enter the **Known Direction** if you don't know the coordinate of the closing foresight point.
Enter the **Actual ID** of the **Known Pnt @ FS.**
You can look at the **Error Analysis** if you want
When you say **[Y]** to **End Trav?**, the raw closure of the traverse will be displayed.

Remember: Known points are those which are to remain fixed (no adjustment)
****

At this time, the coordinates in the **.CRD** file are *unadjusted.* You won't have **adjusted** coordinates until your **.RAW** is processed.

Download the **.RAW** file to the laptop or PC using the **PCLINK** and **INTERLNK** commands. If you download to a directory other than Survis, you must remember to type the entire file path in order for the program to find the file and process it.

If you have the correct coordinates for the closing traverse points entered into the **.RAW** file, a new **.CRD** file can be created at the start of processing. If you have new coordinates to assign to the traverse points, you need to go into **COGO, Points, Load ASCII Point File,** and load the new coordinates into the **.CRD** file you plan to use for processing. You can edit individual points in **Store/View/Edit Points.**

When the **.RAW** file is processed, the traverse closures are displayed. First, the unadjusted closure

will display. You will be prompted, at the bottom of the screen ***Proceed with the Angle Balance?*** You can press Enter or **Y** to continue. It will then prompt you ***Proceed with Compass or Crandall Adjustment.***
At this point, you should have adjusted coordinates in the .XYZ file and for the control points in the .CRD. Any sideshots, double-tied or topography, will also be processed to the adjusted coordinate system.

If you are going to have more than one traverse for a project, which is very likely, then you must process the traverses in the order they were surveyed, using the adjusted coordinates of the preceding traverse, e.g., process Traverse No.1, then process No. 2, using the adjusted coords of No.1, then process No. 3, using the adjusted coords of No. 2, and so on.

When you're done processing all the traverses, check to make sure that the control point coordinates and elevations check.

The elevations are edited to agree with elevations based on closed differential levels. The total stations are not to be used to determine elevation of control points or other important features.

DOUBLE-TIES TO PROPERTY CONTROLLING CORNERS

Section Corners, Right-of-Way Monuments/Pins, Property Corners, Etc.

Configure the Total Station

Set the parameters in the Total Station in much the same way as mentioned earlier for setting up the control traverse. Set PPM, Measurement Units, etc., for the tolerances set forth in the Survey Manual.

Configure the Data Collector

Configure the Data Collector in the same manner as for the control traverse except for a few changes. At the **TRAV** menu, go into ***Preferences.***

This is where you will have some choices to make. Refer to Section 6-15 of the Survey Manual. Most double-ties we make are to be done with **2** position angles, where you would use **0°** and **90°** for the backsight values. In this case, you would set **2-Set Sideshots** to **[Y]**. You can do this by typing it in or pressing the *space bar.*

In the Survey Manual, it says that if the foresight distance is less than 1500 feet (457m), you only need to measure **1** position, backsight value **0°**. In this case, set **Direction Sets** to **[Y]** and turn off **2-Set Sideshots**. The Data Collector will then prompt you for **1** set of angles only.

If it's inside of 1500 ft. you can decide which is easier, shooting 2 positions, or changing the ***Preferences*** and shooting 1 position. Anything outside the 1500 ft. range will still require **2** positions.

Max Set Error- The Manual says the tolerance between sets for double-ties is **10** seconds.

Scale Factor- This will be **1.0000000** unless your working with State Plane Coords. in which case, the value will be .999???????(provided by Survey)

Everything else can be left at the Default settings.

****

To Begin Shooting go to ***Occupy Point***

Enter the **Backsight Point** name

If the coords are in the .CRD file, they will appear here. You can enter them manually or leave it blank if you don't know them.

Enter the **Occupied Point name**

If the coords are in the .CRD file, they will appear here. You can enter them manually.

You have to enter at least one set of coordinates and one elevation to continue, even if they are assumed.

Enter a Bearing-

If the coords of the Occupied point and the Backsight are known (in the.CRD file) the inversed Bearing will display.

If only one of the coordinates has been entered, then a Direction needs to be entered also, even if it too is assumed. Pick a value that is obviously assumed such as **N0°00'00"E,** or **S90°00'00"W**, whatever. You can enter these values by typing **n 0 e,** then Enter, or **n, s, e, or w** can be entered. The software will fill in the rest of the characters. If you are entering a known direction, use the format: Example: N43.3040W and Enter, this will display N43°30'40"W.

Inst. Height--Self-explanatory--This cannot be assumed, these must be measured.

If everything is correct,* Save *and continue.

***Next, Enter the Feature Codes of the* BS *and* Occupied points.**

These will probably be traverse points so enter TRAV and a Description. If these points are already in the .CRD file, these items will display. You don't really need to assign Group No. but you can if you want the BS and Occ.Pt. connected.

If everything is correct,* Save *and continue.

****

***For 2-Set Sideshots, go to* Multi-Angle Sideshots**

Anytime you are taking other than a single, direct angle to the foresight, choose this.

***You will now be prompted to take a* Backsight Direct 0°**-Sight the BS and Enter.

Then **Foresight Direct**

Then **Foresight Reverse**

Then **Backsight Reverse**.

After the Backsight Reverse is taken, a screen will display showing the results of that set of angles. Press any key and go on to the next Position.

The screen will show **Backsight Direct 90°**, Set the Total Station horizontal circle to 90°, Enter

Then **Foresight Direct**

Then **Foresight Reverse**

Then **Backsight Reverse**.

A screen will display showing the results of the 2 sets of angles. Press any key to proceed.

The next screen is ***Multi Angle Sideshot BS.*** This will show the average values of the Horiz., Vert., and Horiz. Distance to the Backsight. It will show your measured values against the calculated values of your coordinates. ***What it's telling you is if you are sighting the right***

Backsight. This is also where you enter the height of the ***Backsight Target.***
If everything is OK, continue.

The next screen is the **Sideshot Info** ***screen***. This will show the results of your foresight shot.
The average Angles and Distances are displayed and optional *unadjusted* FS coords.
This is where you enter the ***FS Target Height,***
the ***FS Point ID,*** 101, 205, etc.
the ***Feature Code,*** RWMON, SURVMON, etc.
the ***Figure No.***(probably don't want one)
the ***Group No.***(probably don't want one of those either)
and a ***Description,*** enter a description of the FS point, 51mm AC R/W Mon, whatever.

If everything looks good, **Save** ***and continue***
****

You've now finished a 2-Set Sideshot to a point. Follow the same procedure for tying the same point using a different Backsight, or from a different Occupied point.

Note:
The point ID given to the foresight shot is now recorded in the .CRD file. When you shoot the point again from another Occ. Pt. or BS, you must give it a different ID. If you call it the same name, the second point will overwrite the first one. Example: you called the RWMON point 201 the first time it was shot, call it 2011 the second time, or call it 201A the first time and 201B the second. You can compare the coordinates of the two points to check the tolerance called for in the Survey Manual. (.25 ft or .076mm.)
If the foresight distance is less than 1500 ft., and you're shooting 1 position only, the setup is like this:

Under ***Preferences***
Turn off **2-set Sideshots (N)**
Turn on **Direction Sets (Y)**
Set **Max Error** at 10 seconds, *Shorter foresights may need higher tolerance.*
Default everything else

You are now prompted for a **Backsight Direct.** It doesn't prompt you for **0°** BS value but that is what you want here.
Then it is asking for a **Foresight Direct.**
Next it wants a **Foresight Reverse**.

*Before prompting you for a Backsight Reverse, you will be asked for some foresight point information like Target height, Feature code, Group no., and Description. Fill in these blanks and as a helpful hint, put the name of the foresight point in the descriptor field. The software is looking for another position or another foresight shot here. You can shoot several points here or you can bail out. You should press Escape(*ESC) *when finished with all the foresight shots.*

This will then prompt you for a Backsight Reverse *at which time you can do that to finish the tie. The reason the software does this is that you have to have a Reverse backsight in order to finish the set of angles to the foresight. It will not assign a point ID to the foresight until a coordinate is calculated. Now you will get a screen which prompts you for the final foresight information, including the Point ID. In the descriptor field you will find the point ID that you assigned to that particular foresight. That way you will get the correct info on the right point.*

NOTE:
In Direction Sets, you are allowed a maximum of ten (10) foresight shots before the software will prompt you for a Reverse Backsight.

TOPOGRAPHY

This is where the plot thickens

In this section, we will cover how to collect topo with the Data Collector and get a good feel for what the system is looking for. Also, we will cover some ***editing*** techniques which have worked successfully with this software package. These are guidelines only as you may find better, easier ways of working with your data.

Configure the Total Station

Make the necessary entries into the Total Station as mentioned before in previous sections such as **PPM,** and **Units (F or M)**.

IMPORTANT:

In order to measure correct zenith angles, you must **Index the Vertical Circle** ***of the Total Station each time the instrument is turned on. Read the instruments Users Manual and follow the procedure for this function. When measuring only one direct zenith angle, there is no way to eliminate errors in the instrument itself. This takes only a few moments and will be crucial to determining correct elevations of the topo shots.***

Configure the Data Collector

Go to *Select Instrument* at the Main Menu
Whichever Total Station you are using, set the Measurement Mode to ***Course Measurement Mode.*** This will be a much faster measuring mode as the Total Station will be taking slightly less precise measurement.

Begin New Job or Continue Existing Job

Files

As mentioned in a previous section, Begin will overwrite existing .RAW files of the same name, Continue will append to an existing .RAW file of the same name. If you try to Begin a new job with a .RAW filename that already exists, there will be a warning which says: **????.RAW Contains Data, Overwrite?** If you're not sure, create a new .RAW file.

You can use a previous **.CRD** file with a new **.RAW**. For instance, if you already have your adjusted control traverse coordinates in an existing **.CRD** file, you should use that to start your Topo survey. This way, your control coordinates and elevations are there when you call up your BS and Occupied points. All you have to enter then is the point ID's and the Inst. Height. There are ways of keeping your control point coordinates safe and not cluttered up with a bunch of topo shots. In ***Coordinate Geometry***, you can manually

manage the points. You can Delete Points in the ***Points*** sub-menu by selecting individual points or by a range, e.g. 1034, 1035, 1040-1090, etc.

If you are collecting **Figures** as you do the Topo survey, this is where you can number those.

At this time, **PCODES.FF** is our only Feature Code file. We will keep this file updated as more codes are added.

NOTE:

When you select a new .RAW file, the .CRD and the .FIG files will default to the same name as the new .RAW file. When the cursor is in each of those fields, you can press* F2 *to display all of the files with that extension in the directory. You can select one of those instead of typing the name in. This is an easy way to recall previously used files.

***If everything is correct,* Continue.**

Next is the* Project Info *screen

Fill it in as in previously mentioned surveys. Everything in this board is for information purposes only and is **not** communicated to the Total Station.

If you are using an ***existing .CRD file****, the units of measurement (F or M) is* ***not*** *changeable, as there are coordinates in that file set to that unit.*

Continue [Y]

***At the* Trav *menu, select* Preferences**, tell the DC what type of survey you want.

You will not be turning **any** types of sets of angles so set the first five fields to **[N]**.
For Topo you will be collecting 1 Direct horizontal angle, 1 Direct zenith angle, and 1 **slope** distance to the foresight point.
There are no sets so there is no **Max Set Error** (leave at **0**).
At the **Scale Factor**, leave it at 1.0000000 unless State Plane Coordinates.
Directions Format- read the top of the screen. Leave this at **0**.
C&R Correction (Curvature and Refraction) should be **[Y].**
Leave **Ignore Prev Descr** at **[Y]** unless you want the same desc. on each point
For topography, **EDM in Fine Mode** should be set to **[N]**.

Save and continue

****

In the **TRAV***menu, Go to* **Occupy Point**

As in the previous sections, Enter the ***Backsight point*** and ***Occupied point*** information. ***Remember,*** *you need at least one coordinate and one elevation to get started. You also need a bearing for your Backsight. These values can all be assumed if you don't know them. If they are in the current* ***.CRD*** *file, they are displayed, along with the bearing.* ***The Inst. Height must be measured****.*

If all is correct, ***Save*** **and continue.**

Next is the Feature Codes of the BS and Occ. Pt. *These are also displayed from the .CRD file.*

The Data Collector is now ready to begin collecting Topo.

Go to **Shoot Sideshot Point,** and Enter

Next you are prompted to **Shoot Backsight ? From ?**

Be sure to set the Total Station horizontal circle to **0°**

Sight the BS point and Enter-

when the BS info is recorded, screen will display showing the BS results. Enter the ***BS Target Height****. The* ***Instr. Height*** *should be there from the previous screen.* ***Check the errors in this screen to confirm you are shooting the correct BS.***

Now you will be prompted to shoot a Sideshot.

The screen will say **Sight Point ?.** *This is the number that it defaults to until you change the name on the next screen.*

At **Collect Angles and Distance,** *press Enter. After taking the shot, a foresight screen will display.*

The H. Angle, V. Angle, Slope Dist, and H Dist are displayed.

You can view the FS shot coords if you want.

This is where you enter the **FS Target Height,***********<u>***This is Important***</u>

Enter the **Point ID-***for topo points start at* **1000.** ***The point ID's for subsequent will increment from whereever you start your numbering. Next point will be*** **1001,** ***then*** **1002,** ***etc.***

Enter the **Feature Code-** from the PCODES.FF file. *As you start typing the feature code,* ***your*** *entry will display at the bottom of the screen. Also, the Feature Code file will display with the codes in alphabetical order. As*

you type the code, the cursor will find the first code with that letter, then the second letter, third, etc.
Example: You want the feature code TOB for top of bank. Press T, the T's appear, press O, the codes beginning with TO will appear, and so on.

Enter a **Figure Number:** *if you're collecting a figure,*

Enter a **Group Number:** *if you want to connect lines between features.*
Enter a **Description:** *Give more information if the feature code does not cover it. If you still need to enter more information, after accepting this shot* **Save[Y],**
***Escape** to the* TRAV *menu and select* **General Comments.** *You can enter any notes or other info for use during editing or for information that should go to the designer. Any mistakes that need to be recorded during the topo survey can be entered here.e.g., wrong Feature Code, wrong target height, etc. You should record your changes for editing here as you cannot edit the .RAW on the Data collector.*

Continue collecting data in this format. Some handy features of the software are that when this screen displays, the cursor is automatically at the *Feature Code* field. It will default to the last code you had entered. The same for the *Target Height* and *Group Number.* .If you are shooting the same feature, for instance, GRND(Ground Shot), where you're not changing the code on each shot, it will hold GRND as the *Feature Code* until you change it. Same for the *Target height* and *Group No.* At anytime, if everything in this screen is the way you want it, press F2 to accept the shot. *This prompt is at the bottom of the screen.*

Be sure that if there are any changes to these entries, the information makes it into the DC. If the rodperson changes the target height and doesn't tell the DC operator, then all the elevations to the foresights from that point on are wrong. If you have accepted shots with faulty entries, don't panic. Before shooting the next foresight, press* ESCAPE. *This will take you back to the* TRAV *menu where you should select* General Comments. *Write a note to yourself as to what the problem is, e.g., Change Pt. 3456 -3460 to tgt.hgt 2.456,* Or *Last 5 shots are BOS, whatever. When you come back to edit this file, you can search for the word* COMMENT. *Then scroll down through the .RAW file and make your changes to it.
HINT: After you make your changes from these Comments, type the word* DONE *off to the side of the comment to show that you have made the change.

Remember:

All data is being stored in the .RAW file until you edit it on the laptop or a PC in a text editor, such as WordPerfect or Notepad. Immediately after downloading, copy your .RAW files to the same name .ORG. These will be your unedited, uncorrupted files of your field survey. This will also be a backup if you completely scramble your files during editing.

MDTRV003.FF (Sorted by Feature Name)

GROUND FEATURES

127 BNDRY	BouNDaRY
3 BOB	Bottom Of Bank
4 BOS	Bottom Of Slope
89 EDGEWAT	EDGE of WATer
21 FL	Flow Line-downhill
90 FLU	Flow Line-Uphill
25 GB	brklin-Grade Break
27 GRND	GRouND shot-survey
95 HIWATER	HI WATER mark
162 MISCDL	MISC. Dtm Lineftp
163 MISCDP	MISC. Dtm Point ftp
35 MISCL	MISC. non-dtm Line
34 MISCP	MISC. non-dtm Point
48 RIPRAP	RIPRAP corner
57 SHRUB	SHRUB
73 THALWEG	THALWEG of stream
74 TOB	Top Of Bank
76 TOS	Top Of Slope
81 TREE	TREE-desc.
50 UHS	Undgrd Hazard Site

MANHOLE FEATURES

107 MH	ManHole
33 MHELEC	ManHole ELECTtric
38 MHSD	ManHole Storm Drain
36 MHSS	ManHole Storm Sewer
37 MHTEL	ManHole TELephone

STRUCTURAL FEATURES

92 ABUT	conc ABUT/ret wall
1 BLDG	BuiLDinG corner
6 BRCOR	BRidge CORner-desc
7 CATGRD	CATtleGuaRD-group
9 CONC	CONCrete-group
13 DROP	DROP inlet-square
105 DROPR	DROP inlet-Round
29 HEADG	HEADGate
83 WALL	pt on WALL-desc
88 WELL	WELL-desc

.SURVEY FEATURES

2 BM	BenchMark-desc
62 RWMA	Alum R/W Mon-desc
54 RWMON	Conc R/W MONument
55 RWPIN	Metal R/W PIN
61 RWREF	R/W metal REF pin
63 SURVMON	SURVey MONument-desc
80 TRAV	TRAVerse point

RAILROAD FEATURES

49 RRCL	RR CenterLine
108 RRCRL	RR CRossing Light
52 RRSW	RR SWitch

ROADWAY FEATURES

41 2FACE	2FACEd sign
102 BITCURB	BITuminous CURB
53 CHEV	dual CHEVron sign
10 CORE	CORE drill hole
11 CULVI	CULVert Invert
51 CULVT	Top of CULVert
66 CURB	top back of CURB
94 EOG	Edge Of road-Gravel
15 EOP	Edge Of road-Pvmnt
106 EOT	Edge Of road-Trail
17 FENCE	FENCE
26 GRRL	GuaRdRaiL pt-grnd
98 JRRL	JuRsey RaiL
32 MAIL	MAILbox
39 MILEP	MILe Post
144 PM	Project Marker
100 PTW	centerline-PTW
56 SHLD	SHouLDer group
58 SIGNM	SIGN Multi-post
59 SIGNS	SIGN Single-post
143 SM	Station Marker
60 SNOWF	SNOW Fence
30 STID	STreet ID sign
78 TRAF	TRAFfic signal-des
79 TRAFBOX	TRAF./signal control BOX

UTILITY FEATURES

14 ELECACC	ELECtrical ACCess
19 FH	Fire Hydrant
20 FIBER	FIBERoptic cable
22 GAS	undergrnd GAS line
23 GASM	GAS Meter
24 GASV	GAS Valve
28 GUY	GUY wire anchor
31 LIGHT	LIGHT pole
40 MISCAB	MISsile CABle
43 POWER	Underground POWER
44 PP	Power Pole
45 PWRPED	PoWeR PEDestal
46 PWRX	overhead PoWeR
96 SANSEW	SANitary SEWer line
97 STRMDR	SToRM DRain line
65 TANK	storage TANK-desc
68 TEL	TELephone line overhead
69 TELBTH	TELephone BooTH
70 TELG	TELeGraph pole
71 TELP	TELephone Pole
72 TELPED	TELephone PEDestal
77 TOWER	TOWER feature-desc
82 TV	undergrnd cable TV
109 VALVE	VALVE
84 WATER	Undergrnd WATER
85 WATHYD	WATer HYDrant
86 WATM	WATer Meter
87 WATV	WATer Valve

FEATURE CODES

The previous page is a list of the feature codes (PCODES.FF) as of Feb.3, 1997 arranged by category. This list is not final but you should have the up-to-date version. As you find new features, let Survey know so that the new codes can be added to the appropriate libraries.

In the Feature Code library, the codes are designated as either a point or a line. By selecting the code itself, you have selected a whole list of attributes which will show that particular feature in drawing. All you have to choose is the Feature Code.

When you load these codes onto the DC, you will load **PCODES.FF**
The processing version of the software will have the ***Feature Control File (.FCF)***

We are using* MDT.FCF *which contains not only the pcodes, but also all the attributes
of that feature. In graphics, this is the file which designates the colors, weights, levels,
sizes, etc., for each of the features that have been surveyed. When you use the Viewer on the laptop, you will see where these items come into the picture (pardon the pun).

The are two kinds of Feature Codes,* Line Features *and* Point Features. *Lines are, obviously, features that are connected.* EOP *or Edge of Pavement would be shown as a line on the ground since it is connected to another* EOP. *A* TREE *is not connected to another tree so this would be a Point feature. Pretty simple.

When you shoot 2 or more line features of the same code **consecutively**, they will connect to one another in the order that they appear in the .XYZ file.
Example: EOP:
EOP:
EOP:
These EOP's will automatically connect in the drawing.

Now if you shoot: EOP:
SHLD:
TOS:
BOS:
EOP:
These EOP's will not connect since they are not consecutive in the file.

To connect line features that are not shot consecutively, you must assign the feature code a **Group Number.** *This will connect the EOP line features and will also let you have more than one line with this feature code.*

Example: EOP/1:
SHLD/2:
TOS/3:
BOS/4:
EOP/1:

Now the EOP/1 will connect to the other EOP/1, the SHLD/2 will connect to any other
SHLD/2, and so on. They will connect in the order they appear in the .XYZ file when they are imported in the graphic viewer or Microstation, whichever you have access to.

Point features will <u>not</u> connect to one another even if they are assigned a Group No.
(at least they're not supposed to)

FILE MANAGEMENT

In the DC software, you have several types of files to deal with and to keep track of. The ***.RAW*** *file will contain all collected data from the field survey as well as any Comments that were entered. This is an ASCII text file that can be viewed, printed, or edited in your text editor. You can execute these functions in WordPerfect, which itself is not in an ASCII format, but when you use WP indicate you are importing an ASCII file. You can do your editing, then send it back as an ASCII file. Before you process an edited .RAW file, it must be in an ASCII format.*

The ***.CRD*** *file is a binary file which will manage the point ID's, coordinates, elevations, and descriptions(includes feature codes and group numbers). Point numbers or ID's cannot be duplicated in this file. Each time you shoot a foresight shot, in the traverse or during a topo survey, this file is being scrolled through to see if that particular point ID is already in the file. For instance, you shot point number 1010 yesterday and came back today to shot another point called 1010. There would be a warning saying* ***1010 already exists, Overwrite it?*** *If you don't want to overwrite it, say* ***N.*** *You will then be given the opportunity to rename the new point. Be careful. If you do overwrite it, it's gone. This is the file that you will use to process your .RAW file. Since all the coordinate information is stored here, you would recall this file to process with.*

Example:

You went out and did a survey with assumed coordinates and elevations of your control points. You may have tied your survey to another job with known project coordinates or maybe the preliminary survey control was done with GPS. Anyway, the coordinates in your .RAW file are wrong and you want to get on the correct coordinate base. You would go into ***Coordinate Geometry****, from the Main Menu. Make sure you have selected the .CRD file that you want to load the correct information into. Under* ***POINTS,*** *select* **Load ASCII Point File.** *You will be asked for the filename of the coordinate list that you are importing. Be sure to tell it where the file is (path). You will asked if you want overwrite protection for the points already existing in the .CRD file. If you have good coordinates coming in then you probably don't care about overwriting. So say* **[Y].** *Once the new coordinates are loaded to the .CRD file, you can process the .RAW files with the good coordinates. All coordinates and elevations assigned to Occupied points and Backsights in the* ***.RAW*** *file will be ignored and the foresight data will be processed with the correct coordinates.*

When you process, there are files that are created. The ***.XYZ*** *file is an* ***ASCII*** *text file containing the Point ID's, Northing, Easting, and elevations of points processed in that particular .RAW file. If you have several .RAW file, then you will also have several* ***.XYZ*** *files. The .XYZ file is overwritten every time you process that .RAW file.*

Also created during processing is a ***.RPT*** *file which is also an ASCII text file. This is simply a readable version of that .RAW file. It will show Occupation and Backsight information as well as all foresight data, including angles, distances, measured heights, feature code info and descriptions. It does not show any processed coordinates or elevations. These are in the .XYZ file. All Comments will show up here also.*

A very useful characteristic of the .RPT file is if there is anything screwy going on during processing, there is a warning called ***UNKNOWN OPERATION*** *which will show up here. During editing you can search for this command and find where to look for problems in the .RAW file.*

Note: This file does ***not*** *get overwritten during processing. It is appended to each time you process and it will get very large if you don't delete it. If you are processing more than once, it is a good idea to blow away this file and only keep the last processing version.*

Figures:

This is the file where any Figures would be stored.

.FF *file-*

We are using ***PCODES.FF*** *as the current feature file. This is an ASCII text file which can be printed. This file is loaded into the DC for use during the field survey. On the DC, when you start typing the Code name, the file is then alphabetized. When, for instance, you want the code* BLDG, *type the letter B, the screen will show the pcode file highlighted on the first feature beginning with B. Type L, the highlight will go to the first feature beginning with BL, then D, and so on. You can type it or scroll through the list, whichever is easier.*

FILENAMES

As of this time, the Department is trying to implement a filenaming plan to be used as a standard format for all DC files. This way, anyone who picks these files will know
from the filename and extension, what is contained in each file.

Since this is an MS-DOS based system, we are using a maximum of 8 characters for the filename and 3 characters for the extension.

The first 4 characters will be the Control Number, e.g. 2222

The next 2 character will be the type of data in the file, e.g., TR for Traverse, **TP** for topography, **ST** for Section ties, or **HY** for Hydrology, **AD** for additional survey.

The last 2 characters in the filename are the file version, e.g., 01, 02, 03, etc.

A filename called 2222TR03 would be Job No. 2222, Control Traverse, Loop 3

The software uses certain extensions to identify the type of file it needs

.RAW *is the raw field data file. This is ASCII which can be printed and viewed in a DOS text editor. You can have several .RAW files to be processed with 1 .CRD file.*

.ORG ***is an unedited copy of the .RAW file which you need to create and save***

.CRD *is a binary file which stores the point information for later recall. This is the file where all functions of Coordinate Geometry take place. When a .RAW file is processed, it is extracting coordinate information from this file. Point numbers or ID's cannot be duplicated in this file.*

.XYZ *is an ASCII text file created during processing. This file will have the same filename as the .RAW file it was generated from and contains the point ID's, northing, easting, elevations, and descriptor information from that .RAW file. This file is overwritten each time the .RAW file is processed.*

.RPT *is an ASCII text file created during processing. It is a readable version of the .RAW file. This file is appended to during processing rather than being overwritten. Therefore, it can get quite large, so delete it if you don't need it. It can be reproduced easily by reprocessing.*

MONUMENTATION

As always, keep concise field notes of the types of monumentation found or set during the survey. Control points, benchmarks, public land survey monuments, property corners, right-of-way monumentation, etc., all need to be accurately described and recorded.

1. Type of monument: ⅝" rebar with alum. cap, ½" rebar with plastic cap, BLM brass cap, USC&GS stainless steel rod, etc.
2. Markings: what is stamped on the monument
   a. Surveyor's number, date monument was set, etc.
3. Size and material
4. Condition of the monument: Is it in good shape? Will it be destroyed during construction? Is it bent and/or does it need remonumented?

Written field notes with sketches and descriptions are required for preparing Corner Recordation certificates. Refer to the Survey Manual (Sec. 6-17 thru 6-32) for instructions.

Summary

This handout is meant to be a guideline in the operation of this equipment and software. Most of the functions have been field tested, others have only been tried under office conditions with test projects. There are going to be questions and comments on the various procedures outlined in this handout. Please feel free to open some discussion on this material.

This system, as most data collection systems are, is coordinate based and geared around a radial type survey. Good judgement and proper procedures are still as important as before when we had less precise methods of measurement. We can take measurements down to unbelieveable precisions but they are useless if not applied properly and with good practices. Remember...its far less damaging to have a faulty measurement on the true line, than to have a precise measurement where the line doesn't exist at all. Keep in mind, this system is only a tool.

Craig L. Brown
Photogrammetry & Survey

Notes:

Part 2:

Editing , Storing and Submitting the Data

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Montana Department of Transportation
Right-of-Way Bureau
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P.O. Box 2011001
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EDITING THE DATA

Version 1.0

In collecting vast amounts of data from a field survey, it is inevitable there will be some editing involved before the data can be accurately processed. Obviously, the best way to edit field data is to do a perfect, error-free survey. That probably is not going to happen. We are human and humans make mistakes. Some of these are very minor and some are serious enough to warrant another trip to the field. Usually, if you follow proper field procedures, most editing can be done with minor changes to the data. Even the best, well-organized survey can require editing in order for the results to be accurate. It may be a wrong target height, or a wrong feature code entered when the data was collected.

Always enter as much information as possible into the data collector at the time of the survey. You may want to keep field notes of your height of instrument and height of signal measurements, etc. All comments, notes and FYIs can be in the files sent to the people needing them. Entering comments in the .RAW file is covered in the Data Collection Overview (Part 1).

This handout will cover primarily editing of the field data before processing. There will be times when you discover other changes after processing. This is where you can go back and edit the data again and process it again. Editing will most likely take place throughout the entire journey to the designer.

Problem areas may not show up until the drawings are created. When editing, go back as far in the process as you can, e.g., if you have a wrong feature code or a target height, go back and make that change in the .RAW file. Otherwise, when the .RAW file is processed in the future, the same mistakes will be carried forward. Changes made in the .XYZ file will be carried forward to the drawing but will not be recreated if the .RAW file is reprocessed.

Some changes cannot be made in the .RAW file such as lines not connecting in the drawing. You can only make those changes in the drawing itself which can be done in the Viewer or in Microstation.

This handout will hopefully give an overview of the editing process and some of the procedures used to get the desired results. We are still building on this system and will appreciate any suggestions and comments that will help to streamline this process. Several crews throughout the state have used this package and have developed varying degrees of expertise. Please share ideas and solutions with each other.

FILES

Before getting into the editing process, it is important that everyone understand the types of files we are working with. The data collection system uses two types of text file formats, ASCII and binary. ASCII (American Standard Code for Information Interchange) is a format that can be printed and can be read directly from DOS. The .RAW, .XYZ, and .RPT are ASCII files.

The .CRD is a binary file that, uses sequences of 1's and 0's to represent characters. This uses less space and is faster in sorting information. However, if you try to print these files, or just look at them in an ASCII editor, you will see only gibberish. If you want to print the contents of the .CRD file, you must first convert it to an ASCII format, which is done with the Survis Coordinate Geometry menu.

WordPerfect format is different from the Survis format. We use Word-Perfect as an editor mainly because it will handle very large files. The other editors included on the laptops, Notepad and your DOS editor, are ASCII format but you will not handle the big files. If your files are 2000 or fewer lines of text, these editors will work fine. Larger than that and you will need to use WordPerfect. WordPerfect will also show any hidden characters or unwanted spaces that could corrupt your file. When you edit a file in WordPerfect, the software will ask you what type of file you are editing. If it is your .RAW file, it will ask if the file is an ASCII DOS TEXT file. You can accept this and the file will be imported into WordPerfect for editing. When you exit the document, it will ask you how you want this file saved. You must send it back as an ASCII DOS Text file in order for the Survis software to read it. Notepad and the DOS editor do not require converting the files back and forth to a different format.

Become familiar with these editors then use your judgement on which to use.

.RAW	ASCII Text file, raw survey data, does not change when processed, changes made in editor only
.ORG	Unedited copy of the .RAW file to be saved somewhere safe
.CRD	Binary Survis file, point manager, updated when reprocessed
.XYZ	ASCII Text file, processed coordinates from .RAW file, overwritten when reprocessed
.RPT	ASCII Text file, readable version of the .RAW file, no coordinates, appended to when reprocessed.

.FIG	Binary Survis file, works with the .CRD file, stores figures; can be created later
.PAR	ASCII Text file, contains parameters set in .RAW file for type of survey
.FCF	ASCII Text file, Feature Control File, used in the Viewer, contains attributes for placing features in graphics, e.g., colors, levels, weights, etc. (MDT.FCF)
.FF	ASCII Text file, Feature file, contains the feature codes assigned to points, (PCODES.FF), loaded to the data collector
.FLD	Design file created in the Viewer, .XYZ file imported to graphics

Notes:

EDITING

Obviously, the easiest way to edit a survey is not to have any editing. The further along you are with your data collector skills, the less editing you will have to do. Yet, even the most experienced users need to know what to do if a mistake is made. As mentioned earlier, be sure to enter any changes into the data collector. This must be done when you are aware what has happened. Go out to GENERAL COMMENTS and make the appropriate entry such as, *change last 5 rod hgts to 2.456*, or *shot 3401 is TOB*, etc. Make these entries immediately. Don't wait until you forget them. The data collector does not have editing capabilities so you must keep a record for making changes later on the laptop or the PC.

Once you have downloaded the files to your computer, you can begin the editing process. First, copy your .RAW file to the same name with the extension .ORG., e.g., 2444TP01.RAW **copied** (not renamed) to 2444TP01.ORG, and save it on disk or on a safe hard drive. You will now have two files containing the same data. If you completely scramble your .RAW file somewhere in the editing process, you always have a backup copy.

Editing the .RAW File

1. To begin editing, first make changes to the entries that you know need edited. You need to locate and make the changes called for in your COMMENTS. Most all editors will have a function to find certain text. In WordPerfect, go to **Edit**, in the upper left of your screen, and pick ***Find and Replace***. Tell it to find 'comment', upper or lower case, does not matter. It will find each command line of COMMENT as it searches through the file. At each of these, make the changes for which you called. When the changes have been made, make a note to yourself that you changed the entries. To do this, type the word 'DONE' at the end of the comment line, to tell that the changes had been made for processing.

Example: _COMMENT_
Change last 4 shots to TOB DONE

This will tell you or anyone else that looks at this file that the feature codes were changed from whatever to TOB(top of bank). Then leave the comment note as is. Don't delete this entry as it will follow along with the file and let everyone know what was changed in the .RAW file. Remember, the .ORG file is still intact.

Once you have made these changes, you are ready to process. (When you will likely uncover more editing to do). If there are problems in the .RAW file, they will show up when you process.

After Processing

Processing will produce an .XYZ and an .RPT file. If there are problems in the .RAW file, the .RPT (Report file) will show a line of text 'UNKNOWN OPERATION'. This could be from a number of causes. In processing, data after this warning is probably corrupt. Find where in the file this is located, probably by point numbers, and go back to the .RAW file and try to fix the discrepancy. Often, this 'UNKNOWN OPERATION' is caused by editing. If you move things around or enter any values by hand into the .RAW file, you stand the chance of corrupting the file.

Command lines in the .RAW file are setup in a strict format. Each of the commands are entered in the format '_TRAVERSE_, _COMMENT_, _OCCUPY_PNT_. Notice the underscores on the ends and inside the command lines. These are very specific to this software and if these are entered wrong, e.g., _TRAVRESE_, instead of _TRAVERSE_, it will puke and give you the 'UNKNOWN OPERATION' in the .RPT file.

COMMENT commands are an example of where problems can occur. The software is looking for a comment after this command line. If you delete the line of text after the _COMMENT_ command, the software is still looking for a comment.

Example:

```
_COMMENT_
        blank space after deleting comment
_OCCUPY_PNT_
```

The software will read _OCCUPY_PNT_ as a comment rather than as a command line for the next data collector setup. Very bad. Leave comments in the space as entered and type DONE when edits are complete.

Repeat Processing with Edited .RAW File

At this point, the changes you made in the .RAW file should be processed to produce a new .XYZ file. The previous one has been overwritten and is gone. The .RPT file has been appended or 'added onto' so you not only have the new .RPT text but you also have the old ones. The new one is appended onto the bottom of the previous ones. Its a good idea to delete the .RPT file prior to processing again. This keeps the report updated and will show any new problem areas which need fixed.

If there are problems in the .RAW file which cannot be determined, go into WordPerfect to edit and under ***View*** (upper left), select ***Show*** ¶. This will turn on the spaces, shown with a dot, and also where hard returns are. There may be some spaces hiding in your file that aren't supposed to be there and are causing problems. Computer software can be very sensitive to unknown characters or out-of-order commands. This one is no different. Usually the problems can be fixed with minor adjustments to the files.

Once the .RAW file is edited to your satisfaction, reprocess the data to get new and up-to-dated .XYZ and .RPT files. You are now ready contact the designer to help import your coordinates into graphics.

Editing Coordinates in the .CRD File

When you process a .RAW file, the software is using a specified .CRD file, containing coordinates, to base the processing on. In a simple scenario, you create a .CRD file when you start a job, defaulting to the same name as the .RAW file. When the data collector is collecting data, the coordinates of the foresight shots are being stored in the .CRD file selected at the beginning. If you are traversing, these are unadjusted coordinates on the data collector. If you are using assumed coordinates in your .RAW file at this time, the coordinates in the .CRD file are at their surveyed position, based on the assumed system.

After collecting the data in the .RAW file you may want to change your coordinate base from assumed to another coordinate system. You may have chosen 50000, 50000 as your beginning coordinates and assumed an elevation of 1000m. Now it is necessary to change coordinates to the State Plane Coordinate system or a local coordinate system, and the elevation to NAD88 vertical datum. There are a couple of ways to do this.

In Coordinate Geometry (Cogo), you can edit the coordinates in the .CRD file. This can be done on the data collector or the PC. In the **Points** menu, go to ***Store/View/Edit Points***. Type in the name of the point you want to edit. It should appear with the coordinates assigned to it from the survey. At this point, type in the new coordinate values, N,E, Elev, Desc., whatever, and ***Save*** it. The software will recognize that this point ID already exists in the .CRD file and will warn you. You will be asked if you want to overwrite the existing point. In this case, you do want to overwrite it to have the updated coordinates in the file. Continue with as many points as you need. This is one way to do this.

An easier and probably safer way to load coordinates into the .CRD file is to create a new .CRD file and load only the new coordinates into it. All that will be contained in this file will be the new coordinates on the new system. The other .CRD file can either be deleted or just not used. You can load these coordinates by hand or, if you have them on you laptop or PC, you can load them into the .CRD file with the Survis software. That is the best way to transfer coordinates so that your input isn't corrupted.

If you now process the .RAW file with the new coordinates, all foresights, traverse and other-wise will be on the new coordinate base. This method is desirable as you can load your control coordinates into one master .CRD file then process all subsequent .RAW files with it. There's no need having several .CRD files when one will work for the whole project. Once the control coordinates are established they can be used throughout the job as usual. The control coordinates should always be verified to ensure they haven't been corrupted.

Final Edit Procedure with Designer

Surveyors and Designers need to coordinate the final edit of data collector files. They are to get together at a CADD station to do this. This allows surveyors to better recognize possible errors when the designer displays the edited files in a digital terrain model using Geopak. Designers benefit by having a person who did the survey present to help them create an accurate design file.

The editing procedure is as follows:

I. The final editing of the .FLD file is to be completed with both the designer and surveyor present.

II. The field crew owns the files and will be ultimately responsible for any editing of these files (see clarification below). All other sections will reference the .FLD file to do design.

III. If the designer finds a mistake or problem, s/he will proceed as follows:

1. The designer will confer with the surveyor to determine to what extent this mistake or problem will impact other processed data within the file. **NOTE: A single outwardly small error may subsequently compromise an entire data file!**

2a. If scheduling allows, the surveyor will correct the problem by editing the files.

2b. If scheduling does not permit the surveyor to edit the file (ie. contractor activities require them to be on the projects), the following process will be followed:

a. If design must continue, the designer can make a copy of the .FLD file to work on while the procedure below progresses. However, **the designer will not send this copy back to the DI directory to replace the original .FLD file.**

Only the surveyor may be given access to the DI directory and replace the .FLD file! Access to required project files on the DI subdirectory on the CADD file server is given by the respective PC Coordinator listed below.

District contacts are the District Engineering Officers. Current District Enginnering Officers as of Oct 1998 are as follows:

Gary Brandt	Great Falls	454-5911
Terry McDonald	Missoula	523-5820
Jack Wilkinson	Billings	657-0231
Dale Boehning	Glendive	377-5396
Dan Zahn	Butte	494-9621

Helena contacts are as follows:

Tim Boucher	ISB	444-7269

Designers may aid the surveyor in this process, but the responsibility rests with the surveyor or his identified representative.

Copying the .FLD file should be avoided if at all possible. **Working on a copy is NOT recommended as it means others referencing the .FLD file will not be aware of design changes; also, the identified mistake may cause other seemingly unrelated data to change! If data changes, continuing to design could prove futile. Copying should only**

be done as a last resort!

b. The designer will send the surveyor a hard copy of both the original .FLD file information and a copy of any proposed corrections to the file.
c. The surveyor will review this information in a timely manner and approve or disapprove the corrections providing explanatory comments. The surveyor will contact the designer to review changes and return all information to the designer for the project.
d. **The surveyor, or his identified representative, will replace the exiting DI directory .FLD file with a cooperatively edited file.** When necessary, the designer and surveyor may need to jointly reprocess the raw data file.
e. It is here noted that the DI directory is backed up to tape each evening. This means the original .FLD file sent to the server will always exit as Version 1 (file name;1) and can be retrieved if necessary.

Storing and Submitting Files

Control Files

Send data that establishes project control to the SU subdirectory of the server. Send this data early since you need this information established to support the integrity of all subsequent data! Do not begin surveys using assumed coordinates. Start all surveys from established and known coordinate points that have been reviewed and OKed. This is to accommodate all systems moving to State Plane Coordinates.

Project Survey Files

Correctly edited files are to be sent to the DI subdirectory on the server. Do not just store them on your PC or laptop or onto floppy disks! Once the final editing has been completed with the cooperation of the designer, the completed files need to be transferred to the DI subdirectory on the CADD file server by the surveyor or his identified representative. Surveyors get access to the server by following the procedure outlined in the section above. **DO NOT SEND DISKS!**

Write a memo to necessary individuals, as you have traditionally done, indicating the transfer of the files. Create a "read.me" information file on the disk to be transferred with the data files. This "read.me" file will list each file and explain file contents for each one. Include any other needed information or comments in this "read me" file that may assist the design. Send a hard copy of the read.me file along with the memo to the District Construction Engineer to show that the work was completed.

Contact your PC Coordinator to get access to the DI Directory for each project.

Things to Remember

1. There is no editing on the data collector. You must download to the laptop or the PC which has an editor.

2. The .RAW file does not change unless you change it in an editor.

3. Your .RAW file is processed with coordinate values contained in the current .CRD file. The coordinates and elevations of the occupied and backsight points, and the BS direction that were initially entered into the data collector .RAW file are ignored. If the .CRD file is new or is empty, the coordinates in the .RAW file will be used.

4. Make as many edits as you can in the .RAW file instead of the .XYZ file and reprocess. Changes made only to the .XYZ file will not show up if the .RAW file is reprocessed.

5. All functions done in the Coordinate Geometry menu are taking place in the current .CRD file. You can edit point values, create points, delete points, etc., but it is happening in the .CRD file only. To get the new values to the .XYZ file, you must reprocess.

6. Keep the .RPT file updated by deleting the old one before reprocessing. This file can grow to monstrous proportions if you just keep appending to it.

7. The .CRD file can also get quite large if you are collecting a lot of topo. You can either go into Coordinate Geometry and delete all but the control points or just re-create the file.

8. Keep files organized. Don't keep duplicate files with a lot of redundant data in them. Follow the filenaming procedures and keep this information straight. A helpful way to organize files is to create a READ.ME text file. This is a simple document created in your editor which you can build and keep a record of your progress. A good way of naming this file is use the control number, then READ.ME, e.g., 2444READ.ME. Put whatever you want in here. Notes about the weather, whatever. Kind of like an electronic diary.

9. *IMPORTANT:*

   Editing the .RAW file, then reprocessing is continual until the desired results are reached. The .XYZ file must be updated as the .RAW file is edited. When the values in the .XYZ file are correct and you're confident to send it on, then create your drawing (.FLD) in the Viewer. Get with a designer and go through the drawing for possible changes to be made there. Some editing can only be done in the drawing so don't try to fix everything in the .RAW file. Some lines will not connect if they are imported from different files. These can be connected on the Viewer.

Remember:

You are responsible for your survey. Your data must be accurate and complete before the next step can begin. Your survey is the foundation for the whole project so if inaccurate data is presented to the designer, it will not get any better from that point on.

GENERAL COMMENTS TO ACCOMPANY DATA COLLECTOR FLOW CHART

I. **Control Traverse is required since the data collectors utilize coordinates and not station/offset.**

a. Test the EDM against an NGS baseline.
   1. Mail the report to Survey.

b. Set control points.
   1. Refer to the Survey Manual.
      a. Control points should be set outside the estimated construction limits.

c. Create an ASCII text file abstract. This abstract should consist of the location, type of monument, set or found, stampings and markings on the cap.

d. File names associated with the control traverse.
   1. First loop or if the project will consist of only one loop the files associated with this loop will be:
      a. ????TR01.RAW, ????MAS.CRD, ????TR01.FIG, etc.

   2. Second control traverse loop the files associated with this loop will be:
      a. ????TR02.RAW, ????MAS.CRD, ????TR02.FIG, etc.

e. Collect data associated with loop 1.
   1. Download files to PC
      a. Copy data collector file ????TR01.RAW to file ????TR01.ORG
         1. The file ????TR01.ORG is not edited.

   2. Process RAW file and create master CRD file (????MAS.CRD).
      a. View angular error. Does it meet the Survey Manual specifications? If not, additional survey is required or errors must be found in the RAW file.
         1. If the angular error is acceptable, balance the angles.
         2. Adjust the traverse using the compass or Crandall method.

   3. Basis of bearing (solar or other acceptable methods).
      a. If the basis of bearing is known at this time, then rotate the traverse to this bearing.
         1. After rotation inverse coordinates to verify rotation angle was correct.

f. Collect data associated with loop 2.
   1. Load adjusted ????MAS.CRD file into the data collector.
   2. File names-????TR02.RAW, ????TR02.FIG.
   3. The second and subsequent loops begin at a known point and close on a different known point.
      a. Refer to the survey manual.
      b. Loop 2 and any additional loops are closed differently than loop 1.

   4. Download files to PC
      a. Copy data collector file ????TR02.RAW to file ????TR02.ORG
         1. The file ????TR02.ORG is not edited.

   5. Process RAW file.
      a. View angular error. Does it meet the Survey Manual specifications? If not, additional survey is required or errors must be found in the RAW file.
         1. If the angular error is acceptable, balance the angles.
         2. Adjust the traverse using the compass or Crandall method.

      b. At this point file ????MAS.CRD contains adjusted coordinates associated with traverse loop 1 and 2.

g. Repeat procedure for any additional control traverse loops.

II. **Bench Levels**.

a. Peg and adjust the level.

b. Vertical datum.
   1. If elevations are to be based on a recognized datum (NAVD88)-contact survey for a listing of bench marks and current data on those benchmarks.

c. Establish level loops through the control traverse points.
   1. Are the closures within specifications? If so distribute the vertical error.
   2. If not, additional levels are required.
   3. Edit the .CRD file so that elevation values equal the level values.

III. Ties to Section Corners, Right-of-Way Monumentation and Property Corners

a. Refer to the survey manual.

b. Property controlling corners are numbered 100 through 199.

c. Property corners (including right-of-way monuments) are numbered 200 through 499.
   1. As a suggestion, the point number for the first tie to point 104 would be 104A. The second tie to point 104 would be 104B. The final coordinates of point 104 would be a mean of the coordinates of points 104A and 104B.

d. Field notes are required listing the type of monument, if it was found or set, markings and stampings, size of monument, etc.
   1. These notes are required for the preparation of corner recordations and for the reconstruction of the right-of-way.

FOR DISTRICT ASSISTANCE: PRIMARY CONTACTS

1. Missoula District	*Tom Benedick **	*523-5864*	*Data Collector, Survey*
	Terry McDonald	*523-5820*	*Computers, Connecting*
Kalispell	*Mark Roedel*	*755-8559*	*Data Collector, Survey*
	*Ed Toavs**	*257-3395*	*Data Collector, Survey*
2. Butte District	*Paul Jagoda **	*285-4732*	*Data Collector, Survey*
	Bill Fogarty	*782-9327*	*Data Collector, Survey*
	Dan Zahn	*494-9621*	*Computers, Connecting*
3. Great Falls District	*Beth Scofield*	*265-6821*	*Data Collector, Survey*
	Levi Doll	*265-6821*	*Data Collector, Survey*
	*Mike Ostertag **	*454-5921*	*Data Collector, Survey*
	Gary Brandt	*454-5911*	*Computers, Connecting*
4. Glendive District	*Danny Hood **	*365-2877*	*Data Collector, Survey*
	Dale Boehning	*365-5296*	*Computers, Connecting*
5. Billings District	*Gerry Brown **	*538-8732*	*Data Collector, Survey*
	Jack Carlson	*245-9820*	*Computers, Connecting*

If there are problems, District personnel should contact the above people. If the primary contact person(*) is unavailable or unable to answer questions, they will contact Photogrammetry & Survey or Joe Reed

Secondary contacts:

1. Dave Davis Photogrammetry/ Survey-Helena 444-7609 or 444-6020.

a. The primary contact should request assistance. Information is then relayed to others.

2. Joe Reed
MapVision Systems,Inc.
Round Rock, TX
1-888-249-2598 toll free

3. Tim Boucher Viewer
406 444-7269

Part 3:

MDT Survey Data Viewer

Tim Boucher, P.E.
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MDT Survey Data Viewer (Version 1.1Beta)
Application Overview

February 5, 1997

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Montana Department of Transportation
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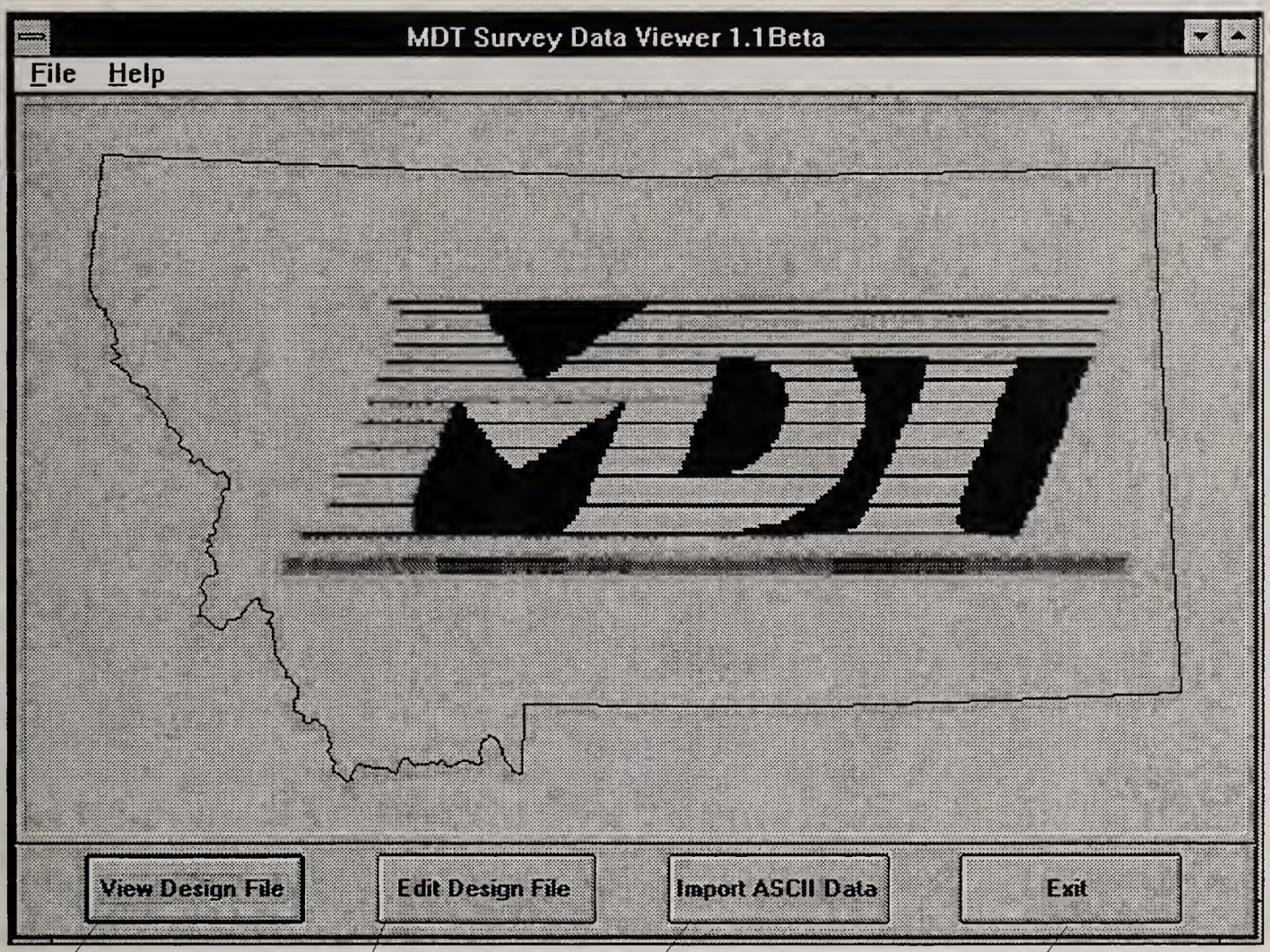
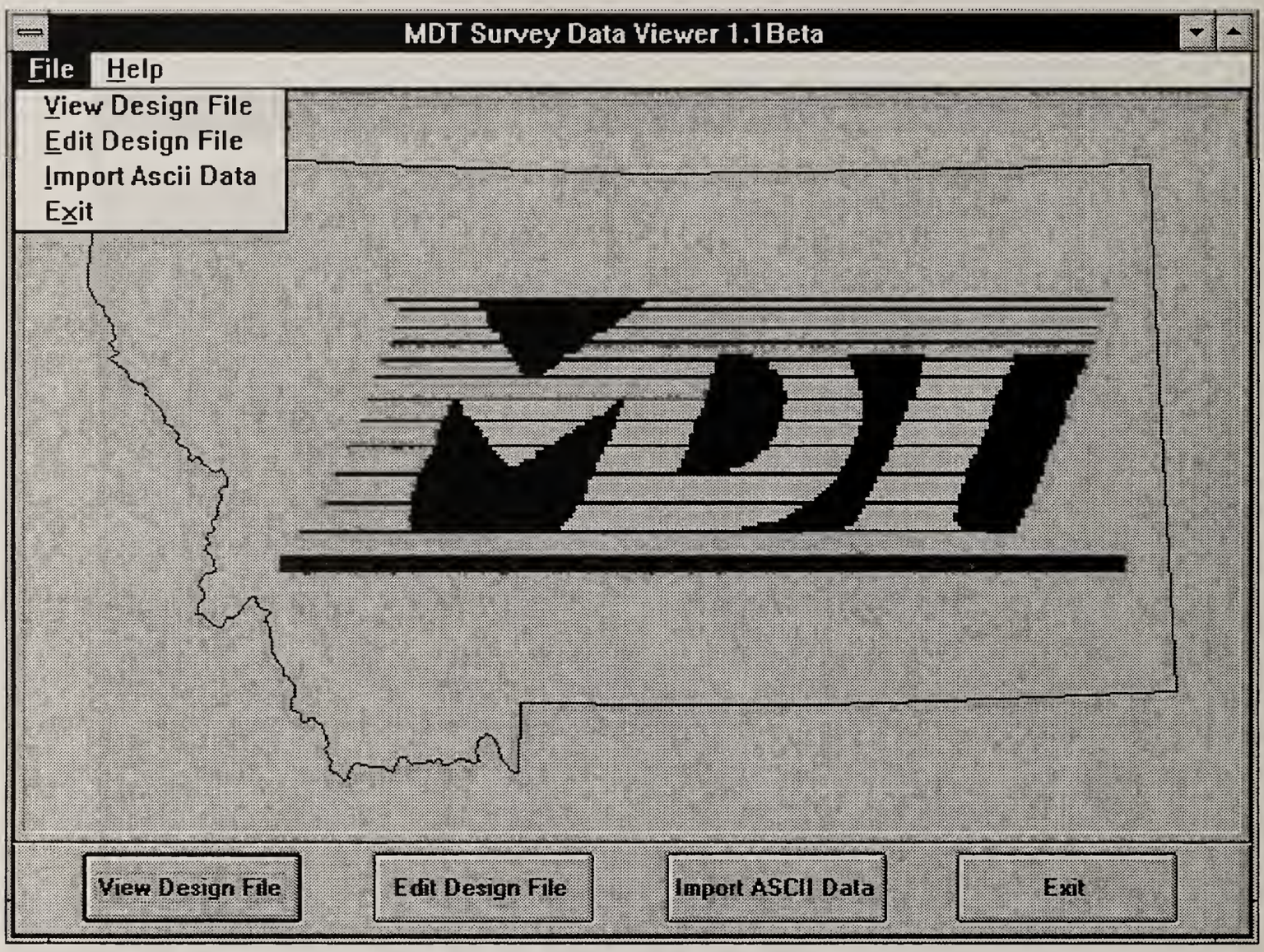
Introduction

Data Viewer Main Program Module
Startup Form (1.1Beta Test Version)


MDT Survey Data Viewer 1.1Beta
File Help
View Design File
Edit Design File
Import ASCII Data
Exit
View Existing Design File
Edit Existing Design File
Import to View, Create New, Or Add to Existing Design File
End Execution of Data Viewer Application

Main Form File Menu

Survey Data Viewer Application Main Program Module
Startup Form File Dropdown Menu Items



File Dropdown Menu/Main Form Command Button Options:

View Design File - Open & View Existing MicroStation Design File (No Editing Available)
Edit Design File - Open Existing Survey Design File (*.fld) for Editing (No Importing Required)
Import Ascii Data - Import Survey Ascii Data (*.xyz) to either:

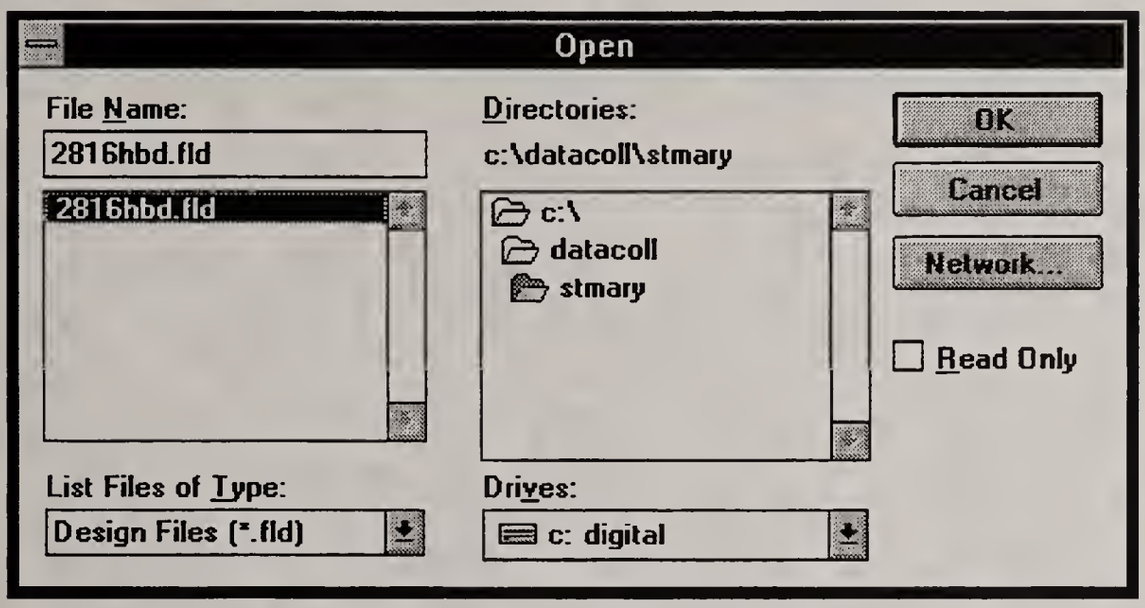
1.) View Graphically (2D or 3D) (No Editing & No Files Saved);
2.) Create a New Design File (*.fld) (Includes Edit and Save Capabilities);
3.) Add to an Existing Design File (*.fld) (Includes Edit & Save Capabilities)

Exit - Ends execution of MDT Survey Data Viewer Application Program

View Design File Option (Activated Using File Menu Or Command Button)

Provides tool for user to view existing MicroStation Design files (2D or 3D). No file editing.

View Design File Process Forms Progression



Allowable File Types Are Currently:

Survey Design Files (*.fld)

All Files (*.*) (Allows user to view any MicroStation design file that they have access to.)

Using the mouse, the user can:

Click on the **Drives:** dropdown list box arrow to view and select any drive which is currently available.

Double-click in the **Directories:** list box section in the center of the window to open folders (which represent directories); or, click on the scroll bar arrows to view additional directories (folders) not currently visible in the list box.

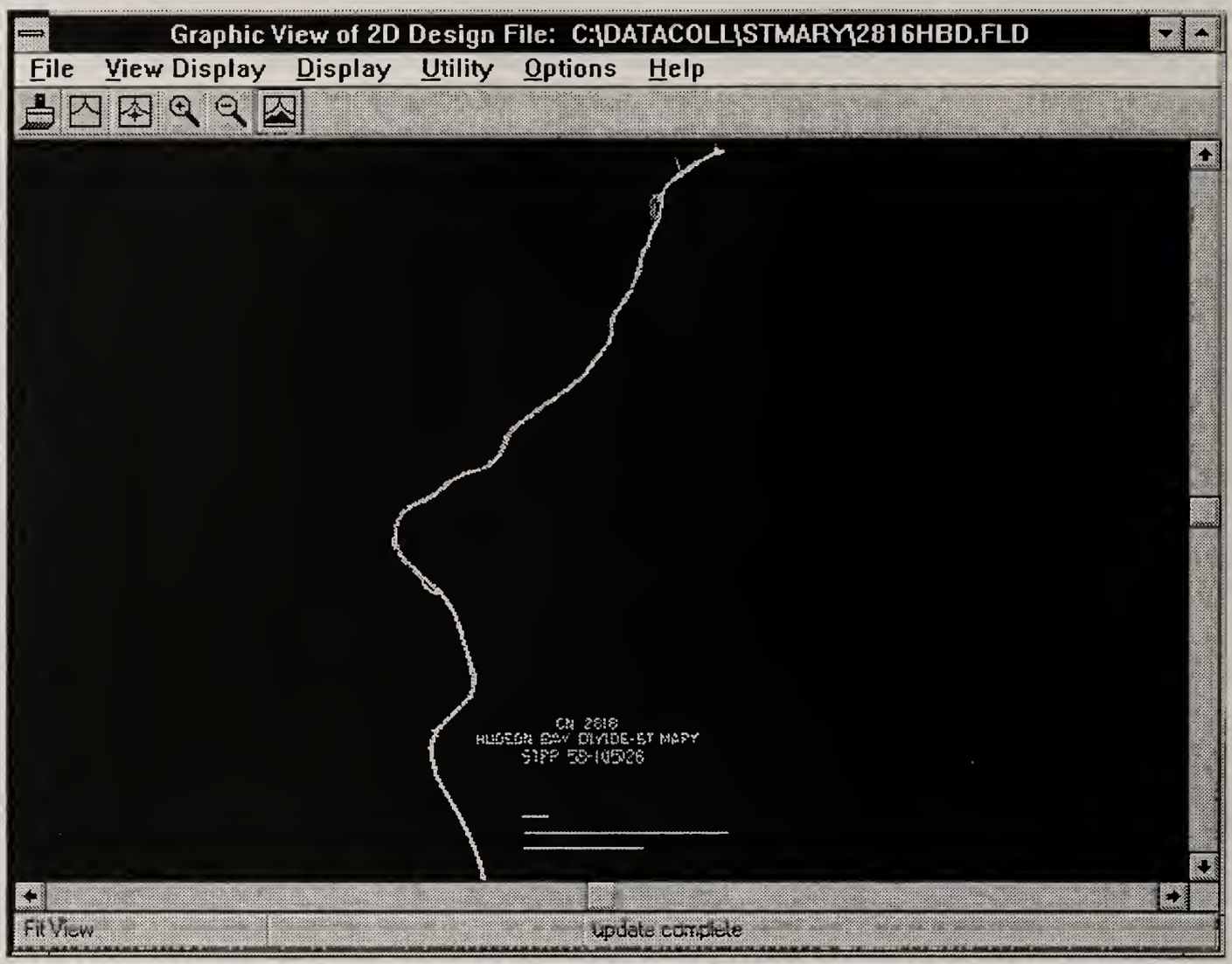
Click on the **List Files of Type:** dropdown list box arrow to view and select the file name extension filter to use when displaying files contained in the current selected directory (folder).

Click on the desired file in the **File Name:** list box located on the upper left portion of the window to select the desired file; or, click on the scroll bar arrows to view additional files not currently visible in the list box.

Once the desired file is selected, the file name appears in the **File Name:** selection box in the upper left portion of the window.

The user then simply clicks on the **OK** button to open the design file for viewing.

The file will be opened and displayed in the Graphic Data View form as shown below:


Graphic View of 2D Design File: C:\DATACOLL\STMARY\2816HBD.FLD
File View Display Display Utility Options Help
CN 2816
Fit View
Update complete

As can be seen, the graphic display form has a number of menu items and tools (command buttons). In the View Design file mode, only view display tools are available. No editing tools are available. The view display tools (also activated from the **View Display** menu) are:

Update View - Redraws the graphic image on the screen to refresh the screen.

Window Area - Allows the user to change the view display to a sub-area of the current displayed area. The user is prompted to selected the view window origin and the opposite window corner (use left mouse button).

Window Center - Move a point in the current view to the center of the window. The user is prompted to give the point to center about (use the left mouse button).

Zoom In - Move in closer to a point in the current view. The user is prompted to give the point to zoom about (use left mouse button).

Zoom Out - Move further out from a point in the current view. The user is prompted to give the point to zoom about (use left mouse button).

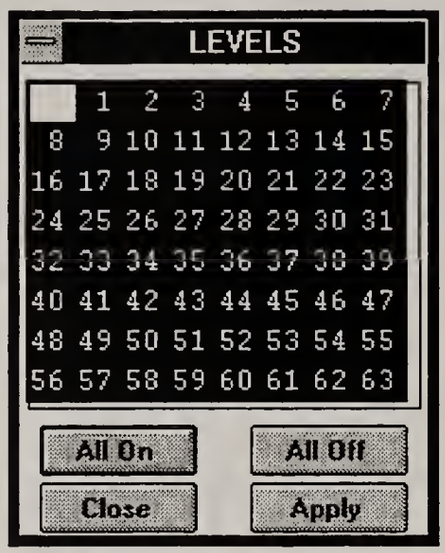
Fit View - Fit the entire view (all of the design file elements) into the window.

File menu options available are:

Open Design File -	Activates **Open** form to allow user to select another design file to open for viewing.
Open Redline File -	Opens redline file on top of currently open design file. File opened is created as same name as opened design file with .rdl extension if .rdl file does not already exist. Without editing capabilities is only useful if .rdl file already exists.
Close Redline File -	Closes redline file if currently open.
Compress Redline -	Saves any changes made to redline file (any changes done are permanently applied to the redline file and can no longer be undone).
FileDesign Redline -	Saves redline file settings (views, levels activated, element types, etc.).
Exit -	Closes the View Design File graphic display form and returns the user back to the main form.

Display menu options available are:

Levels - Activates **Levels** form which allows user to turn on and off viewing of design file levels. [Highlighted (black) levels are on.]

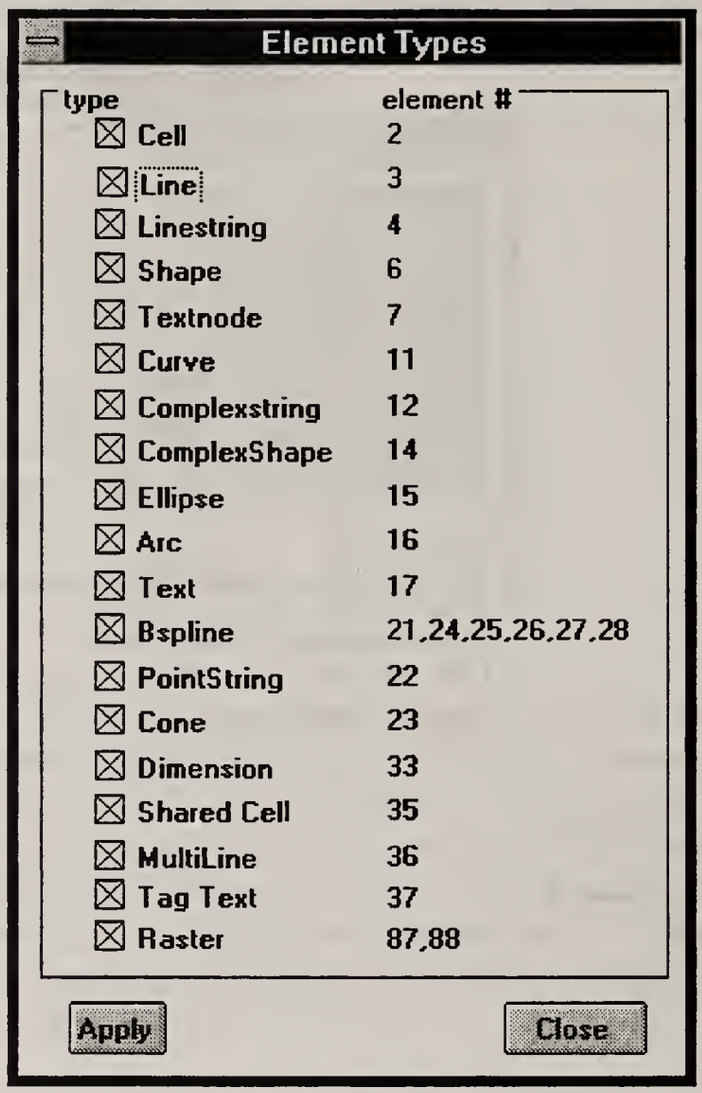


To turn off levels, use the mouse to click on the level number so that it is no longer highlighted (black), then click on the **Apply** button. To turn on all levels click on the **All On** button, then click on the **Apply** button. To turn off all levels click on the **All Off** button, then click on the **Apply** button. When done, click on the **Close** button to close the form. (Note: The user must always click on the **Apply** button in order to apply the selected changes. Otherwise, the changes will not be made.)

Levels Used - Activates **Levels Used** form which allows user to see which levels in the design file are actually being used (contain design elements). [Highlighted (black) levels contain design elements.]

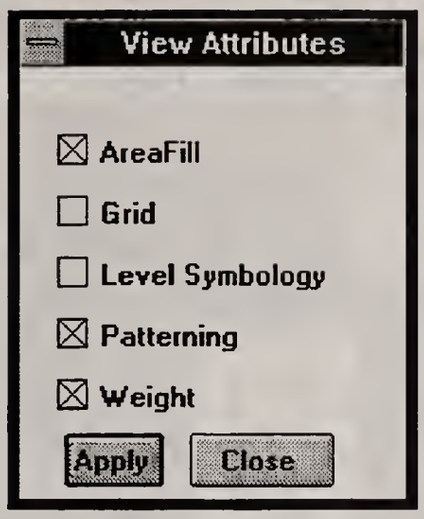
Click on the **OK** button to close the form and return control to the Graphic Data View form.

Element Types - Activates **Element Types** form which allows user to turn on and off viewing of design element types. [Selected (X) element types are on.]



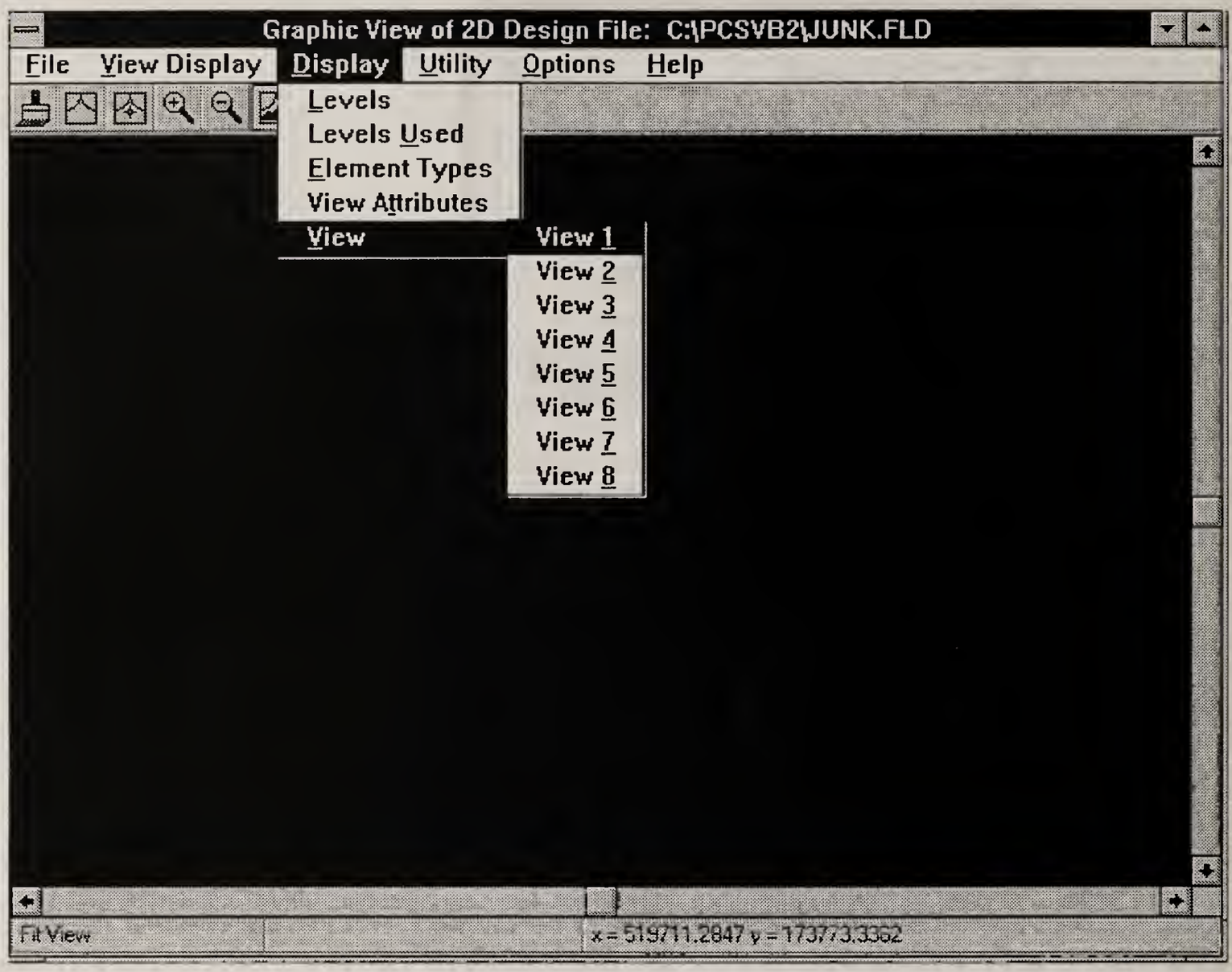
To turn off element types, use the mouse to click on the box next to the element type so that it is no longer selected (X), then click on the **Apply** button. When done, click on the **Close** button to close the form. (Note: The user must always click on the **Apply** button in order to apply the selected changes. Otherwise, the changes will not be made.)

View Attributes - Activates **View Attributes** form which allows user to select design file attributes to be viewed.. [Selected (X) view attributes are on.]



To turn off view attributes, use the mouse to click on the box next to the view attribute so that it is no longer selected (X), then click on the **Apply** button. When done, click on the **Close** button to close the form. (Note: The user must always click on the **Apply** button in order to apply the selected changes. Otherwise, the changes will not be made.)

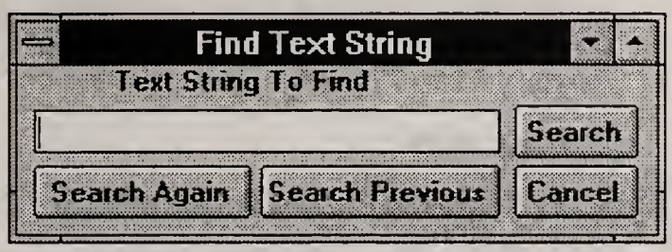
View - Activates **View** pullout menu which allows user to select which view to display on the graphic data view form.



To select a different view for display, use the mouse to click on the desired view number (View 1, View 2, ..., or View 8). The view will then automatically be opened on the Graphic Data View form. (Note: This is most useful for viewing of 3D files which usually contain the Top view in View 1, the Isometric view in View 2, the Front view in View 3, and the Right view in View 4.)

Utility menu options available are:

Text Search - Activates **Text Search** form which allows user to search design file for desired text string.

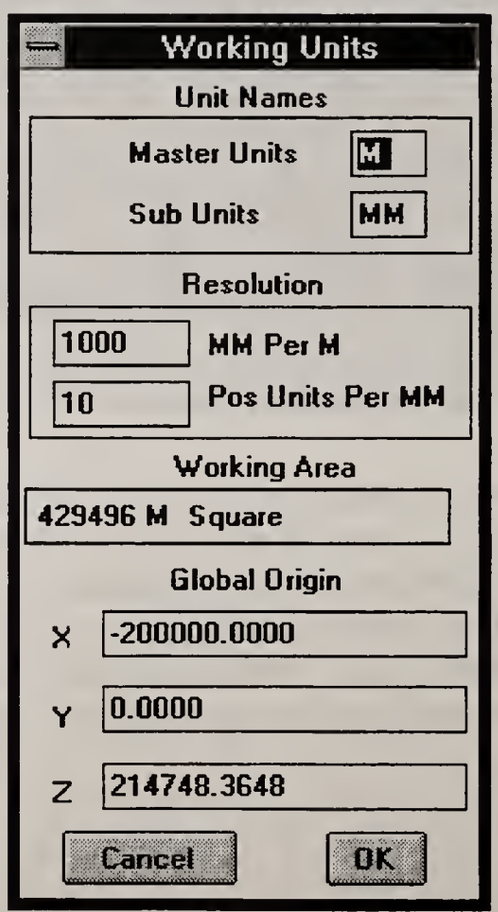


To search for text string, type the desired text string into the **Text String to Find** text box, then use the mouse to click on the **Search** button. To search for the next occurrence of the text string, click on the **Search Again** button. To search for the previous occurrence of the text string, click on the **Search Previous** button. When found, the text string will be located, zoomed into in the graphic data view form window, and highlighted. When done, click on the **Cancel** button to close the form.

Analyze - User is prompted to identify element to be analyzed. After using the left mouse button to click on the desired element, an **Information Display** form is activated which contains all of the information for the selected element..

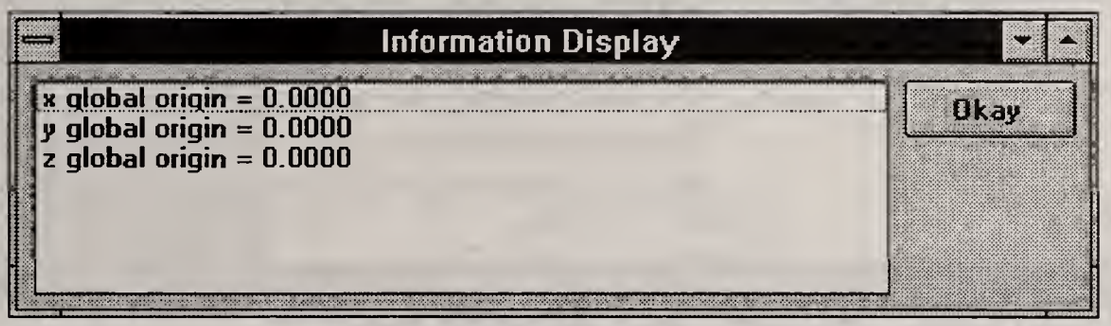
To view information not visible in the Information Display list box, use the left mouse button to click on the scroll bar arrows and scroll the information up and down through the list box. When done, click on the **Okay** button to close the form.

Working Units - Activates **Working Units** form which allows user to see working units information for the current design file.



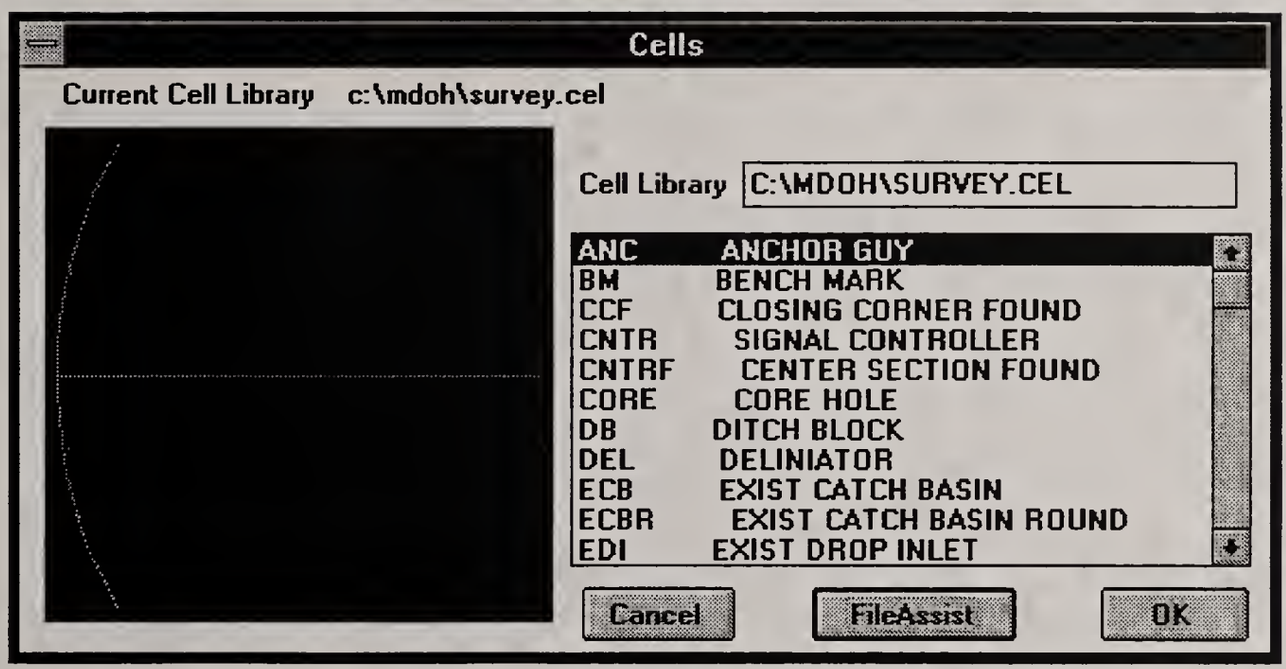
When done, click on either the **Cancel** or **OK** button to close the form.

Get Global Origins - Activates an **Information Display** form which allows user to see



global origins information for the current design file.
When done, click on the **Okay** button to close the form.

Cells - Activates **Cells** form which allows user to see view cells in cell library currently attached to the design file and/or attach another cell library

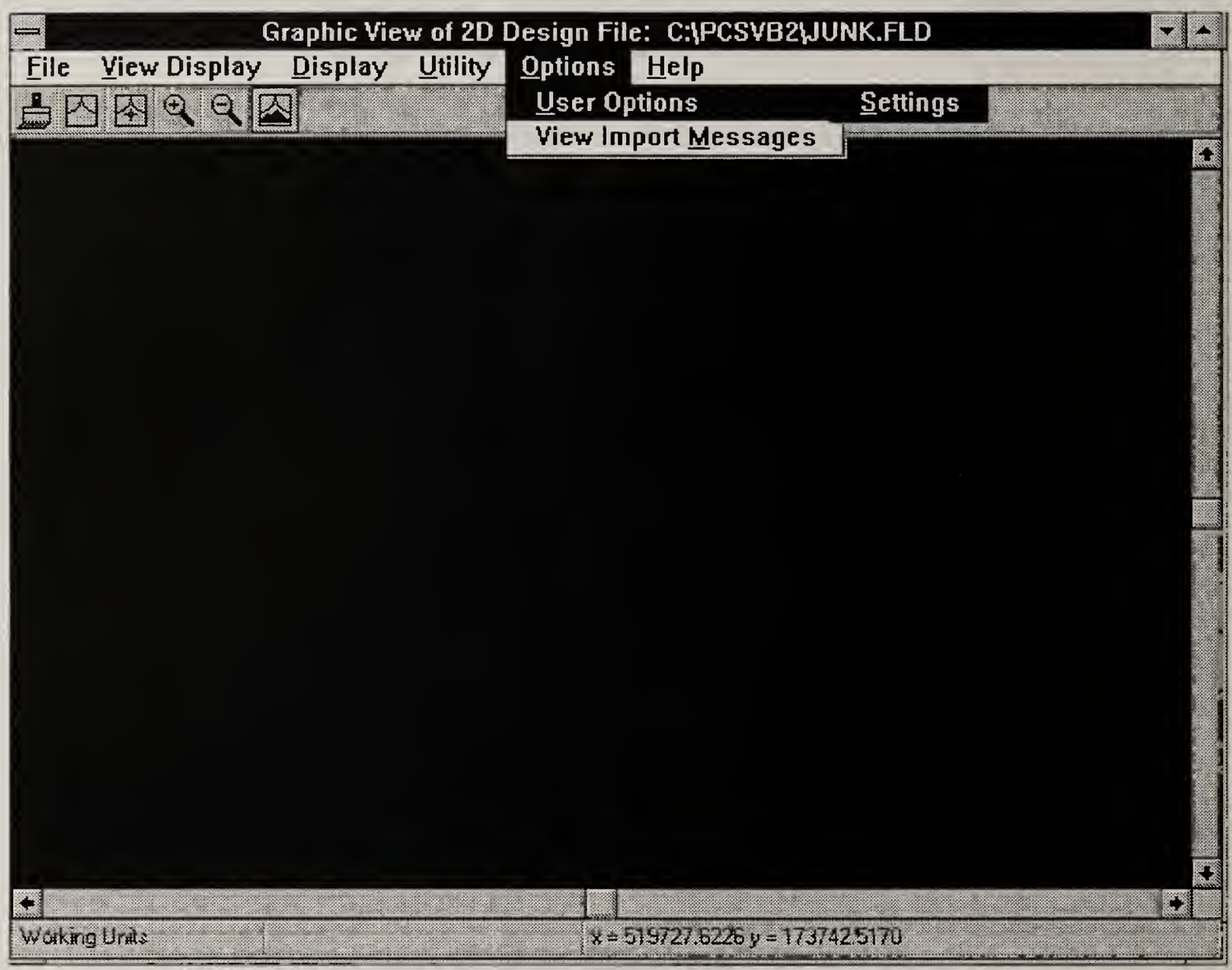


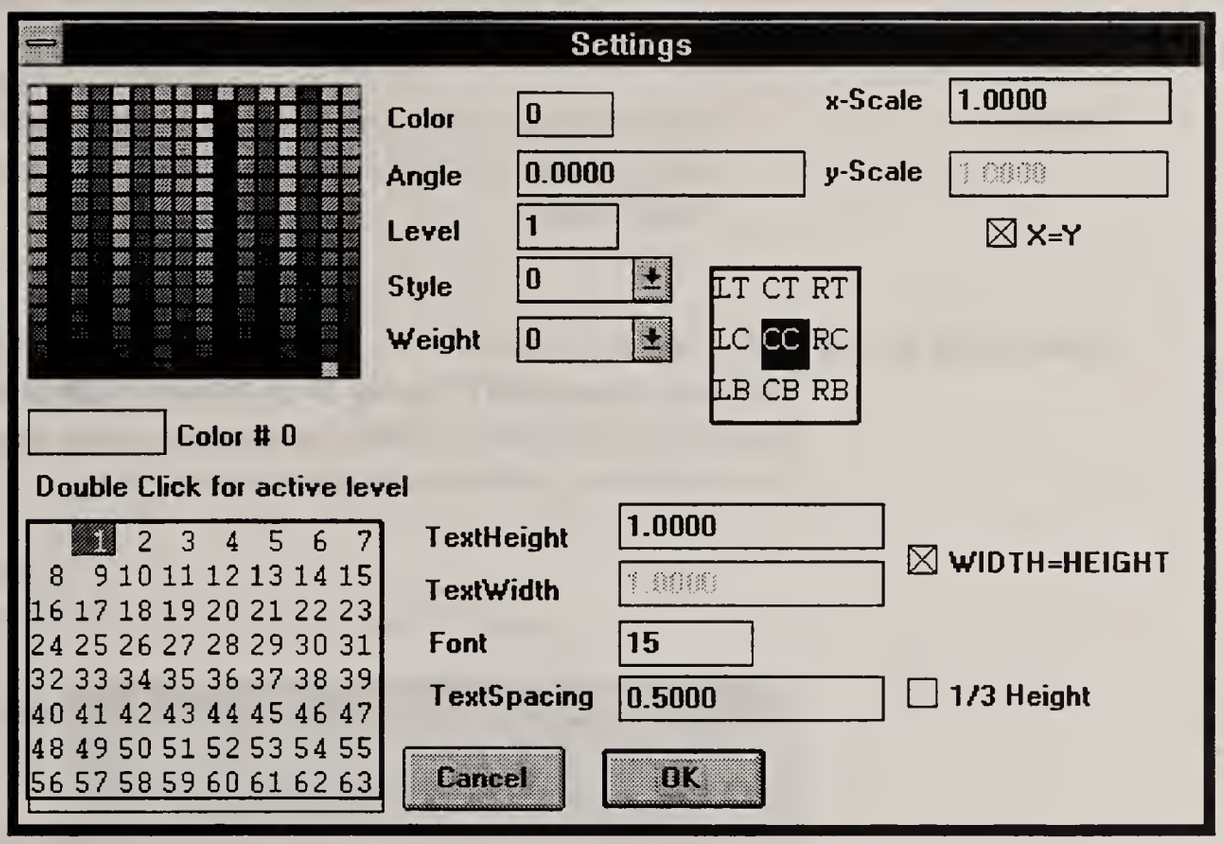
and view its cells.

To view cells, use the left mouse button to click on the cell name in the list box. The graphic view of the cell will automatically appear in the graphic window to the left of the list box. To find cell names not visible in the list box, use the left mouse button to click on the scroll bar arrows to scroll the cell names up and down in the list box. To attach other cell libraries for viewing, click on the **FileAssist** button. Another form will be activated, allowing you to search for and select another cell library. When done, click on either the **Cancel** or **OK** button to close the form.

Options menu options available are:

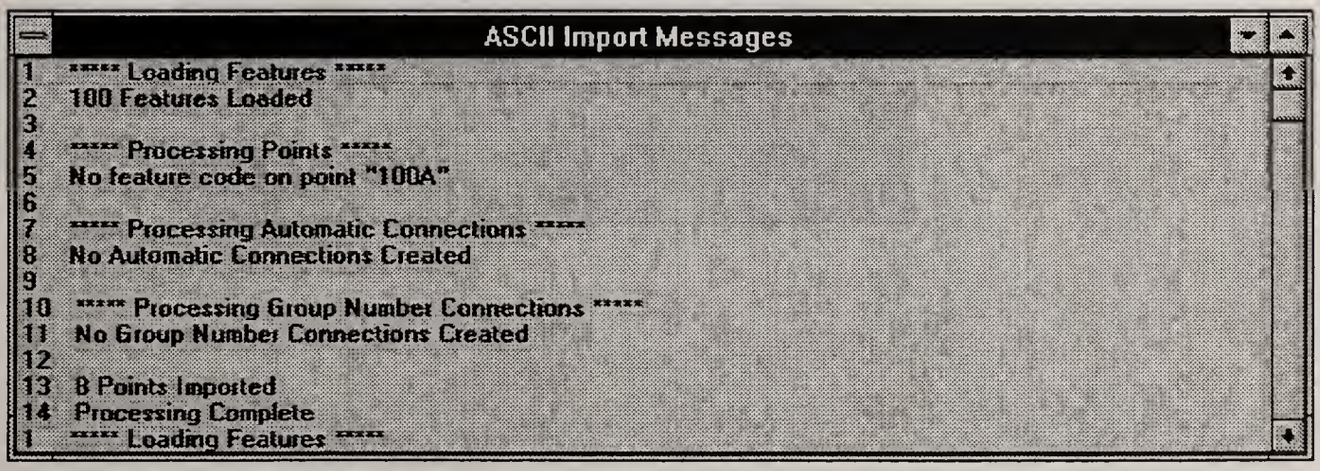
User Options - Activates **Settings** pullout menu which allows user to view current settings for design file.
To view the design file settings, use the mouse to click on the **Settings** pullout menu option. A **Settings** form will be activated which contains all of the current design file settings.





When done, click on either the **Cancel** or **OK** button to close the form.

View Import Messages - Activates **ASCII Import Messages** form which allows user


ASCII Import Messages
1 ***** Loading Features *****
2 100 Features Loaded
3
4 ***** Processing Points *****
5 No feature code on point "100A"
6
7 ***** Processing Automatic Connections *****
8 No Automatic Connections Created
9
10 ***** Processing Group Number Connections *****
11 No Group Number Connections Created
12
13 8 Points Imported
14 Processing Complete
1 ***** Loading Features *****

to view messages generated during Ascii (*.xyz) data import.

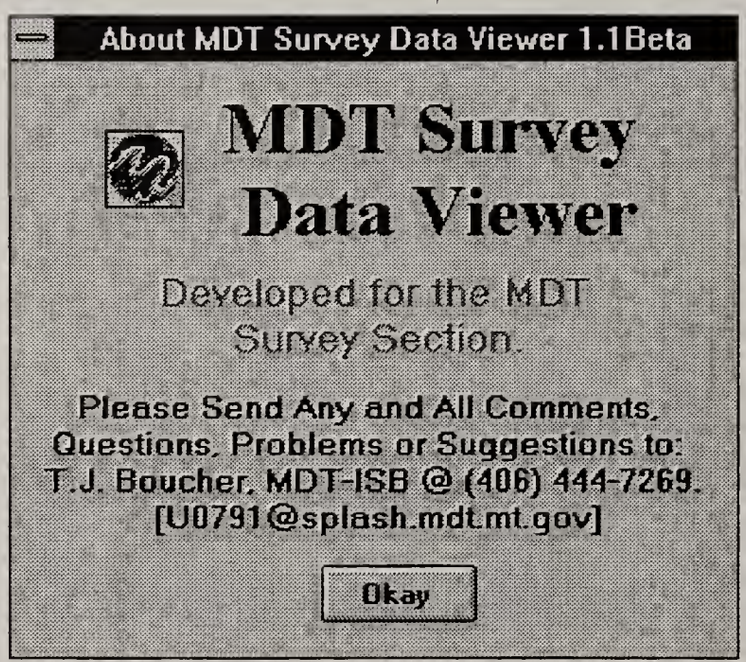
To view information not visible in the ASCII Import Messages list box, use the left mouse button to click on the scroll bar arrows and scroll the information up and down through the list box. When done, double click on the control button [-] in the upper left corner of the form to close the form.

Help menu options available are:

Contents - This option is not yet active. When enabled it will allow the user to activate standard Windows help for the MDT Survey Data Viewer.

About MDT Survey Data Viewer 1.1Beta -

Activates **About MDT Survey Data Viewer 1.1Beta** form which provides user information about the application and point of contact for support and problem reporting and resolution.


About MDT Survey Data Viewer 1.1Beta
MDT Survey Data Viewer
Developed for the MDT Survey Section.
Please Send Any and All Comments, Questions, Problems or Suggestions to:
T.J. Boucher, MDT-ISB @ (406) 444-7269.
[U0791@splash.mdt.mt.gov]
Okay

MENU MAP FOR SURVEY VIEWER

Main Form Menu Options:

- File
- Help

File

- View Design File
- Edit Design File
- Import Ascii Data
- Exit

Help

- Contents
- About MDT Survey Data Viewer 1.1Beta

Graphic Data View Form Menu Options:

- File
- Edit
- View Display
- Display
- Utility
- Options
- Help

File

- Open Design File
- Open Redline File
- Close Redline File
- Compress Redline
- FileDesign Redline
- Exit

Edit

- Connect Line Strings
- Extend Line String to Point
- Delete Part of Element
- Delete Element
- Undo
- Redo

View Display
- Update View
- Window Area
- Window Center
- Zoom In
- Zoom Out
- Fit All
- Fit View

Display
- Levels
- Levels Used
- Element Types
- View Attributes
- View > View 1 thru View 8

Utility
- Text Search
- Analyze
- Working Units
- Get Global Origins
- Cells

Options
- User Options > Settings
- View Import Messages

Help
- Contents
- About MDT Survey Data Viewer 1.1Beta

As with all Windows applications, use <tab> key or mouse to move between selections in forms and menus.

Use left mouse button to respond to prompts to select items and to accept element selections. Use the right mouse button to reject element selections.
Use update view to redraw all visible elements. When editing, use Undo and Redo to fix erroneous operations, use Compress Redline to save editing changes without exiting.

Part 4:

The Jagoda Papers

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DATA COLLECTOR TRAINING

FILE MANAGEMENT SETUP

1. Setup your file management on the computer.
   A. Go to File Manager: we are going to create a directory for your Survis Programs.
   1. Click on c:\ , this will highlight this directory.
   2. File
   3. Create directory
      a. Type:Survis
         -This will create your directory where all survey programs and data will be stored.
   4. Click on this new directory "Survis".
   5. File
   6. Create directory
      a. Type:Field
         -This will create a subdirectory under Survis. This is where you will store your Survis Field program for the Data Collector.
   7. File
   8. Create directory
      a. Type:Office
         -This will create another subdirectory under Survis. This is where you will store your Survis Office program.
   9. File
   10. Create Directory
      a. Type:Projects
         -This will create another subdirectory under Survis. This is where you will store your individual Projects you surveyed. Create a subdirectory under this Projects directory for each Project, ex. 3075 (this is the project's control number).
   11. File (with the Survis directory highlighted)
   12. Create directory
      a. Type:Viewer
         -This is where you will store your Viewer program.
   13. Create directory
      a. Type:Merge
         -This is where you will store your Merge .fld program.
   14. Your files are now setup to load all the Data Collector Programs.
   15. Loading the Programs from a disk onto the computer.
      A. Put the disk with the Survis Field Program in the "A" drive.
      B. Click on the Field Directory (to highlight it).
      -If you are using a disk that already has the subdirectory Field on it, skip #6 above and click on Survis instead of Field. It will create the subdirectory Field automatically.

C. File

D. Copy

From:Type in "A:"

E. OK

-This will copy from "A" drive onto your highlighted Field directory.

F. Yes to all

16. Do the same with the Office, Viewer and Merge Programs as you did in #14.
17. Next install the Viewer Program.
    A. Get out of File Manager and go into Program Manager.
    B. Insert disk 1 in drive A:
    C. From Program Manager, select File menu and choose Run...
    D. Type a:\setup and press enter or OK.
    E. If prompted to replace newer files with older files, select No. When prompted insert disk #2.
18. Next install the Merge fld Program.
    A. Complete this process the same as in #17.
19. Next we will create an individualized Directory.
    A. File
    B. New
        1. Click on Program Group
        2. Description: Type:Your Name, ex.Jim Bob.
           Group File: leave blank
        3. OK
    C. To copy the wanted programs into this group:
        1. Highlight the wanted program, ex. Word Perfect.
        2. Then press Control & mouse click & drag & drop.
    D. Then save the setups:
        1. Options
        2. Save settings on exit

-Then shut down windows and come back in and then turn off Save Settings.

DATA COLLECTOR SETUP

1. When first starting with the data collector, it needs to be reformatted. At the D: type "FMTSRAM /128" <enter>. See handout #1 for more detailed instructions.

2. Next connect the data collector to the laptop or office computer using the cables provided with the data collector. This can also be completed when the data collector is in the docking station using the cables provided.

3. Copy the Field program files to the data collector. (See handout # 4 for more information, but not needed at this point)

A. On the data collector you should now be in the C:\> drive. If you are still in the D: drive type C:\ to change into the c:\ drive. If this did not work, the formatting in #1 did not work. Try #1 again. If that didn't work call for HELP!

B. Type:pclink

-This will connect the data collector to your computer.

C. On the PC go into the Data Collector Program.

1. Type:interlnk (No second "I")

-This will connect the data collector and PC so they can "talk" to each other. 2.Type:cd field

-This will connect you into the Field program you put into the File Manager on page #1. Cd stands for change directory. You should now have c:\survis\field on the screen.

D. Type:copy *.* e:*.* <enter>

-Be sure there is a space between the following: copy space *.* space e.

1.If it asks (yes/no/all), type:a (for all).

-This will copy all the Field Directory files from your PC to the data collector. At this time it should be 9 files.

4. On the data collector hit ALT&F4 to exit out of PCLINK. The SWAP key on the data collector is used to move to the right or left screen.

5. On the PC type:cd..

-This will put you back to the c:survis\

6. Now you are ready to go to the field and collect survey data. HAVE FUN!

COLLECTING DATA

- On the job training and use of the Practical Help Guide by Craig Brown..

* More to be added at a later date.

DOWNLOADING FROM DATA COLLECTOR TO COMPUTER

1. At the c:\ on the data collector type:pclink <enter>
   -If the pclink does not work, soft boot the data collector by hitting CTRL\ALT\DEL.
   -Or use the Transfer Files Program on the Data Collector. (It works!)
2. On the computer go into the data collector program.
   A. Type:interlnk (No second "I")
      -This will connect you with the data collector.
   B. Type:cd projects
      -This will put you into your projects subdirectory under the survis directory, you created this on page #1.
   C. Type:copy e:\project file name.*
      -This will copy all the data collector data under this file name, ex. 3075ad01, into the projects subdirectory.
      -It will say how many files were copied if this was successful.
   D. The downloading is now completed.
      1.To get out of the pclink on the data collector hit alt&F4.
      2.On the PC type:cd..
         -This will put you back to c:\survis>
   E. You are now ready to process the data on the Office Program.
   F. Make a original copy. This is the copy you never touch! Make this copy before any processing or editing is done. DO IT NOW! Go into the file manager, in windows, to do this. This cannot be done in the Survis Office program because there is to many characters to transfer to the directory that is wanted c:\survis\projects\3075\3075.raw.

PROCESSING DATA

1. At c:\survis> Type:SO
   -This will put you into the Survey Office Program.
2. Process and/or adjust raw survey data <enter>
3. Existing data collection files <enter>
4. Enter the file location and name into the File Entry Box.
   A. For the raw data Type:c:\survis\projects\your file name.raw
      -This is the data we downloaded from the data collector to the c: drive, survis directory, projects subdirectory.
   B. Do the same for the coordinate file. Type:c:\survis\projects\your file name.crd
   C. Skip the figures box.
   D. The features file path should automatically come up, if not type:
      c:\survis\office\pcodes.ff
      -The features codes we stored in the office subdirectory.
5. Continue, <enter> on the "Y".
6. <enter> to proceed.
7. A. Right arrow over to "Adjust"
   B. Compass adjust <enter>
8. The processing is completed. Your .XYZ file has been created, this will be used to create your .FLD design file (the viewer).

EDITING DATA

- Use of the Practical Help Guide by Craig Brown.
- See handout #11.
- Hands-On training.

1. Go into Word Perfect.
2. File
3. Open
4. Next find the file that needs editing. It should be in c:\survis\projects\"project name".
   A. Double Click on c: , in the Directories box.
   B. Double Click on survis.
   C. Double Click on projects.
   D. Double Click on the project name where the data is located.
   E. Go to the box on the left side and Double Click on the file to edit.
   F. Convert file format Box:
      1. Convert file format from: ASCII (DOS) Text
      2. OK
         -This converts the data into a readable format.
5. Let the EDITNG begin!
   A. To make sure you do not edit hidden program information, do the following:
      1.View
      2.Put a check mark by Hidden Text, Show and Reveal Codes.
         -This will open a screen on the bottom of your screen that shows hidden program information that you do not what to change. Example ,a certain number of spaces between the data.
6. After completion of the editing:
   A. Save
   B. The Save Format box appears:
      1. Click on ASCII(DOS)Text.
      2. Click on OK.
         - This saves your information into the format the data collector programs read.
7. File
8. Close
9. File
10. Exit
11. Now you must reprocess the data you edited, or if it has not been processed, process it.

See page #6 for processing information.

   A. Exit out of windows
   B. Shut off computer for about 10 seconds.
   C. Turn computer back on.
   D. Get into the Data collector Program.

-This must be done to keep from corrupting the Windows and Data Collector Programs. This must be done every time you go from Windows to Data Collector or Data Collector to Windows. At this point you are asking "WHY", I don't know. Its a computer thing. Contact the computer experts if you need a better understanding.

TIP: If you have a multi-mistake, a lot of mistakes that are the same. An easy, fast way to edit this when you are in Word Perfect:

1.Edit
2. Find and Replace
   - Type in what you want to find and what to replace it with.
     And use the: Find Next, Replace and Replace All as you need them.

TIP: To search for unknown operations ,which are errors:

1. Go into Word Perfect.
2. Bring up the report(.rpt) file you want to search for errors in.
3. Convert file ,Yes.
4. Edit
5. Find and replace
6. Type in "unknown operation".
7. Click on find next.
8. If there is an unknown operation make a note of it. Then go back into your raw data and edit it (correct it). The data will now need to be reprocessed.
9. Save it. Remember to save it as ASCII(DOS)text.

TIP: A helpful way to edit your raw data is to multi-task. This lets you view your .fld file in the viewer while you are in Word Perfect editing the data. First open up your .fld file in the view mode preferably, next use the alt-tab key to open up Word Perfect and then you can go back and forth using alt-tab or keep both open on the screen.

CREATING .FLD DESIGN FILE WITH THE VIEWER

- Use of the Practical Help Guide by Tim Boucher.

1. Double Click on MDT Survey Data Viewer.
2. A version Mismatch message will appear. Click on OK.
3. Import ASCII Data
4. Create New Design File
   A. Enter what you want to call this .fld file.
   B. Continue
   C. The Local/State Plain Coordinates box will appear. Click on the options that relate to your project.
   D. Continue
   E. The ASCII Data box will appear:
      1. Click on Select XYZ.
      2. Find your .xyz file that you want this .fld file created from. It should be located as follows:
         a. C:\ (double click)
         b. Survis (double click)
         c. Projects (double click)
         d. Your project's name (double click)
         e. In the box on the left click on the .xyz file wanted.
         f. OK
   F. You should now be back at the ASCII Data box.
      1. Click on Select FCF.
      2. Find the FCF file.
         a. c:\ (double click)
         b. survis(double click)
         c. Office(double click)
         d. In the box on the left, click on the mdt.fcf
         e. OK

   G. You should now be back at the ASCII Data box.
      1. Click on Import.
         -Your design file is being created.
   H. The ASCII Import Messages box appears. Close this out by clicking on - and close.
   I. Click on Fit All, it is the window looking icon.
   J. This is your design file. Use the icons as described in Tim Bouchers help guide.

K. You are now a Survey Expert, Data Collection Expert, Computer Expert, and Design Expert! You probably didn't realize you knew this much!

5. Use the Merge .FLD program to merge all your .fld files as needed.

DATA TRANSFER TO THE DI SUBDIRECTORY

Once the final editing has been completed with the cooperation of your designer, the completed files need to be transferred to the subdirectory DI in the CADD Access Server. The designer will need to help you with this transfer, most people in the field do not have access to this directory. A "read.me" file will need to be created and transferred with the files. This "read.me" will explain what the files are and any other needed information or comments from you. Handout #3 is an example of a memo and hard copy of the read.me file. This was sent to the District Construction Engineer to show that the work was completed.

Contact your Engineering Officer to get access to the DI Directory for each project.

DATA COLLECTOR TIPS

- To make the curser and screen darker or lighter at the c:> type:ct.com (then adjust the contrast).

- Do not use a letter first when naming a point:
  A1 NO!
  1A YES!
  -Do not use 0, because someone might take it as the letter O and enter O1 as the point. When you adjust the data it will not recognize O1, but it will recognize 01.

- Make sure you have all the newest , updated, greatest programs. Contact either Paul Jagoda or Tim Boucher.

- Use one .crd file for the whole project.

- Use cell library numbers for describing signs, (see Handout # 2).

- Use a group number one time, even if the feature codes are different. This helps make editing easier.

- The horizontal angle can be locked for individual cross sections. This makes cross sections follow a straight line, but this does not have to be done.

- Adjust the vertical index at each setup. You might have to change your gun to the manual setup.

- In the point description line, put an * for other information on this point, ex. Field notes, read.me file. This will tell the designer there is more information on this point in another location.

- If you have c> instead of c:\>, this means you lost Path information. Thus, the autoexec.bat file needs to be copied to the data collector. After copying do a soft boot, ctrl/alt/del and the c:\> should now appear.

- If you want to find "LINE" between two points. Tell the data collector you want to Radial Stakeout, it will tell you the angle you need to turn to get to that next point. Once you are on line you can go into shoot sideshots and continue cross sectioning.

- To Setout points or do elevation checks:
  1. Occupy point.
  2. Const.
  3. Radial stakeout.
  4. Shoot backsight.

- Check the distance error; should be within mm's.
- Check the vertical error; should be within cm's.

5. In the stakeout box:
   A. Calc cut/fill (Y) Yes does not save the data.
   B. Enter the point you are shooting.
   C. Shoot the picket or point and it will tell you information to setout that point.
   D. Check the cut/fill, this will tell you if your elevation corresponds to the coordinate elevation. If this is a big difference and you are sure its not your mistake, you will want to save this elevation.
   E. To save your new elevation:
   1. At calc cut/fill (N) No saves data.
   2. Save (Y)
   3. Quit (Y)
      - This will override the existing elevation with your new elevation, but it will not change the X or Y coordinates.
6. To view your new coordinates:
   A. COGO
   B. Point submenu
   C. Edit/store view points.
   D. Enter point name

- To create a readable coordinate file from the binary(.crd) file, which is garble, to a text format(.xyz), which is readable:
   1. Const.
   2. Write ASCII file.
      - This will write the .crd data to a readable .xyz file.

- To transfer a coordinate file received from the Survey Department onto the data collector:
   1. If you edit them in Word Perfect remember to save them as ASCII(DOS)Text.
   2. After transferring the coordinate file to the data collector:
      A. Begin new job.
      B. Create a blank .crd file, example 3474.crd.
      C. Load the Coordinate file:
      1. Const
      2. Load ASCII Point File.
         - Load goes from text to binary.
         - Write goes from binary to text.
      3. Type in file name, example 3474edph.asc. This is the file received from Survey.
      4. Overwrite (yes)
         - It will tell how many points where loaded.

      -Now the blank .crd file you created (ex. 3474.crd), has all the 3474edph.asc data in it. Use this .crd file, (ex. 3474.crd), for the whole project.

      -.ASC (.xyz) files you can read, .CRD files are garble.

PC/LAPTOP TIPS

- To copy a single file from the PC to the data collector: c:\survis>copy pcodes.ff e:\pcodes.ff
(copy)(space)(file name)(space)e:\(file name)

- To copy a disk to another disk: c:\diskcopy a: a:

- To copy files in file manager: hold down the CTRL key, mouse click, drag and drop the file where you want it.

- To move files in file manager: hold down the ATL key, mouse click, drag and drop the file where you want it.

- To copy data to a disk: c:\survis>copy 2370.met a:*.*
(copy)(space)(file name)(space)(a:*.*)

- To merge files: c:\copy filename + filename + filename newname

(Copy)(space)(filename)(space)(+)(space)(filename)(space)(+)(space)(filename)(space)(newname)

- To edit coordinates:
  1. Coordinate geometry <enter>
  2. Point or figures <enter>
     a.Define point
     -Enter the new point coordinates.
  3. Process/adjust <enter>
  4. Compass adjust <enter>
     -This will not change your raw file.

- To load new coordinates from a disk or a coordinate file:
  1.Data collection/const <enter>
  2. Arrow over to Const <enter>
  3. Load ASCII Point File <enter>
     - This loads ASCII file to the current .crd file.
  4. Enter the coordinate file name, ex. 2370.met <enter>
     -This will override all coordinate points with the same point ID.

- To process\adjust data you must have the proper file path typed in the file entry block, ex.
C:\survis\projects\3075.raw (if this is where your data is located).

- Batteries:

1. If you have problems with your batteries get new ones from Dave Balkovetz.
2. While using the data collector if you get the message "low batteries, change batteries now" or the screen zooms in, you must exit out to the "c" prompt and shut off the data collector. Hopefully this will save your data. Then put it in the docking station and down load your data.

3. If you have battery problems you may have too much data stored in the data collector. Make copies of your data then delete the data from the data collector. It was observed that around 2000 points stored was when problems started. A blank screen may also appear.

4. If you are having a good day and really whipping out the points, ex. 500 points by lunch. Down load at lunch and charge the data collector in the docking station over the lunch break. The more points you collect the more juice is drained from the batteries.

- Get a LARGE color printout of your .FLD file for your final walk through\editing. This helps to find mistakes or points missed. Contact your design personnel to help with this.

- If your PC does not have interlnk, it must be installed on your PC.

1. Type:Edit config.sys
2. In the configuration system block, Type:device=c:\dos\interlnk.exe
3. Save it and exit out of the config sys.

- If the SO won't work at the c:\survis>

1. Type:cd office
2. Now at the c:\survis\office, Type:SO

VIEWER TIPS

- The following are some files that are created when you create a design file(.fld):

.rdl	This one you can delete.
.tmp	This one you can delete.
.err	Keep it, it has message information.
.ipo	Keep it.
.odg	Keep it, it is a copy of your previous design(.fld) file before you added to it or edited it.

- Create a .fld file every day and then merge the .fld files together as needed. This way if you learn one day had bad data you can delete just that day and merge everything but that day back together. This saves an editing nightmare.

TO CALCULATE FIGURES

By: Mark Cyr — Revised by: Paul Jagoda
December 1997 — March 1998

The following can be used to calculate coordinates using figures in the data collector. This will produce for example the coordinates for all the centerline stations or for an offset from centerline. These can then be used when doing Radial Stakeout.
NOTE: This will not calculate the offsets correctly on Spiral Curves.

PROCEDURE

After setting up files and loading points [these points need to include the PT & PC for a tangent and the PC, PT, & Radius Point (method to get radius point coordinates follows below) if you are on a curve] into CRD file then proceed as follows.

1) Go to Survis Office SO
2) Go to Coordinate Geometry then File and Enter Files to use.
3) Move to COGO
4) Select Figures Sub-menu
5) Select Edit Figures
6) Enter 1 @ Current Figure
7) Enter 0 @ Ref. Figure
8) Enter Alignment @ Type
9) Enter CL, Offset LT or RT, R\W LT or RT, etc... @ Description. (Hit space bar)
10) Enter feature code @ Line Code (e.g. TRAV, CL, EOP, R\W, etc...)
11) Enter beginning station of figure you want to create @ Beg. Station (e.g. 94749.40 for station 947+49.40). For example this needs to be the PC station on a curve even if you want your points to be calculated starting at a different station on the curve (this station will be entered later).
12) Enter Y @ Edit Points
    A) Edit Figure Points screen will appear
    B) Press yellow shift and the "+" key
    C) Select Segment Type will appear
        D) If Figure 1 is a curve select Horizontal Curve if Figure 1 is a tangent select Tangent and then enter
        E) If you select Horizontal Curve a Curve Segment Ids. will appear
        F) Here you will need to enter the point numbers you have assigned to the PC, Radius Point and PT points in your CRD file
        G) If you had not previously loaded these points into your CRD file press ESC until you are back to COGO menu and enter these points via the Points Sub-menu, Edit/Store/View Points
        H) After points are loaded repeat steps 1 thru 3
        I) Just enter thru steps 4 thru 10
        J) Repeat steps 10.A thru 10.F

K) After entering point numbers assigned to PC, Radius Point and PT press Y on Save if you are happy with input

L) This should put you back to the Edit Figure Points screen

M) Here press ESC and this will put courser @ Delete? (Y\N) on the Edit Figures screen

N) If you are happy enter N

O) Enter Y @ Save? (Y\N)

P) Select Calc. Points Along A Figure and Enter

Q) Calc. Points Along An Alignment screen will appear

1) Enter Y @ Select An Alignment
2) Enter whatever number (e.g. 2000) you want to begin your figure points with @ First New Point Id. Example: 3000 (points that are not presently in your file)
3) Leave Beg @ Station blank if you want to beg. @ first point along the figure
4) Leave End @ Station blank if you want to calculate entire figure (e.g. PC to PT along a horizontal curve, PT to PC along a tangent)
5) @ Offset enter amount of offset LT [negative (will appear as + in .XYZ file)] or RT [positive (will appear as - in .XYZ file)] of CL or leave @ 0.00 for CL
6) Enter whatever interval you want calculated e.g. every 20m, 25ft, etc. Note if you are in meters and you enter 20 the figure will be calculated every 20 m
7) If you are happy enter Y @ Do It
8) @ this point do not panic if data collector appears to do nothing, long figures may take some time to calculate
9) When calculation is complete collector screen will inform you of numbers assigned within the figure
10) These are stored in your CRD file and can be used @ any time now
11) From here ESC to COGO menu

Inverse between a select few points to confirm they are correct. Check the bearing, distance and curve data.

CALCULATING RADIUS POINT COORDINATES

By Paul Jagoda
March 1998

1) If you do not have the radius point coordinates, you must calculate them.
   A) Calcs
   B) Intersect/Traverse
   C) Enter the first point: Ex. 10335 (PT)
   D1) Enter Angle or Direction from 10335 to next point: Leave Blank
or D2) N 63.4201 W (bearing of line N 63°42'01" W) OR 10335✱10020+90 [10335 is occupied point. ✱means backsighting. 10020 is a POT. 90 is degree of angle.]

This will put you on the bearing line to the radius point.

   E1 & E2) Enter distance from 10335 to next point: 150 (radius of curve)
   F1) Enter second known point: 10423 (PC)
   G1) Enter Angle or Direction from 10423 to X PT: Leave Blank
   H1) Enter distance from 10423 to X point: 150 (radius of curve)
   I1 & I2) Pick solution from PT 10423: Type in either **A** or **B**
      A: S 40°53' 57.6" W - 150.00
      B: N 14° 58' 34.0" E - 150.00
   J1 & J2) Enter the intersection point ID: What ever you want to name it. (1RD) Then the solution will appear.

DATA COLLECTOR
FOR STOCKPILES

By Lance Spooner
January 1998

1. Turn on data collector.

2. At the c: prompt type sf; then hit enter.

3. Pick Data Collection and Cogo.

4. At the main menu pick Select Instrument (enter appropriate data).

5. At the main menu pick Begin New Job.

6. At the File Entry Menu - At this point you need to create your files. It is best for future reference if you use the stockpile number or control number, but you may call them whatever you choose.

   Create a RAW, CRD, and FIG file.
   At .FF push F2 and pick PCODES.FF.
   At continue type Y and enter. (You may use F2, to view current files already in the data
   collector at each file entry spot.)

7. At Project Info. - Fill in appropriate info (Be sure to choose F or M for feet or meters-check
   your instrument to make sure they correlate).
   At continue Y and enter.

8. At TRAV pick Occupy point

9. At Occupy point - The program will want a backsight point ie:1A (beginning of baseline, a paint dot will do) and assign it coordinates ie: 10000 & 10000 & ELEV. 1000. (It is not
   necessary to measure baseline, it will be used only to pick your x-sections and get right angles).
   At occupied point pick a point number ie:1B
   Now toggle down to Enter a Bearing.
   Pick a bearing ie: N00.0000E type it in and enter.
   Measure your Inst. height and type it in and enter.
   At saveY enter.

10. At BS-1A OCC-1B- You may enter the appropriate data or enter through this screen.

11. At TRAV pick Shoot Side Shot Point

12. At Shoot BS 1A from 1B - Sight your BS prism and hit enter on the data collector.

13. At Sideshot BS - Toggle down and enter prism heigh.

14. At Sight point 2- At this point you are ready to start shooting your foresights. You may use as many pogos (mirrors) as you like, but remember if your pogos (mirrors) are not all the same height you must enter the correct height for the pogo (mirror) you are shooting at the Sideshot Info Screen. Sight the pogo you want to shoot and hit enter, the data collector will collectangle and distance and assign this info. to point number 2.
Now toggle down to Figure Number: [N] and type Y hit enter .
The program will bring up Select A Figure.
At this point enter 1 at Current Figure, then toggle down to the bottom , USE?
Type Y enter .

15. At Sideshot Info - Enter the appropriate data pertaining to the shot. Your first figure should be a 0/0 (knot/knot) section. (Figure number should be 1)
Save Y and enter.

16. At Sight Point 3 - Take another shot just a couple feet away to complete your 0/0 section.

17. At Sideshot Info - Enter appropriate data pertaining to the shot (point ID should be 3 and Figure number should be 1)
Save Y and enter.

18; At Sight Point 4 - This should be your first x-section point. Shoot it and enter Figure 2.
Shoot the remaining points in this x-section, using figure2.
Repeat this procedure for each x-section and a 0/0 x-section.
Each x-section should have it's own figure number.
Each x-section should have two or more points.

19. When finished with all the x-sections hit ESC or Quit.

20. At TRAV - Pick Check Backsight - Collect Angles & Distance enter. This will allow you to shoot your BS and compare info with original data.
At the bottom of the screen it asks if you want to save new BS? Enter[N] no.

21. Now toggle over to CONST
Pick Earthworks
Pick Stockpile or Borrow Pit Volume

22. At X-Sections Figure List

Here you enter the number of x-sections including 0/0 at begin and end. (ie: if you had 6 x-sections enter 1-6.

Description (ie: stockpile number).

Calc Volume? Y enter.

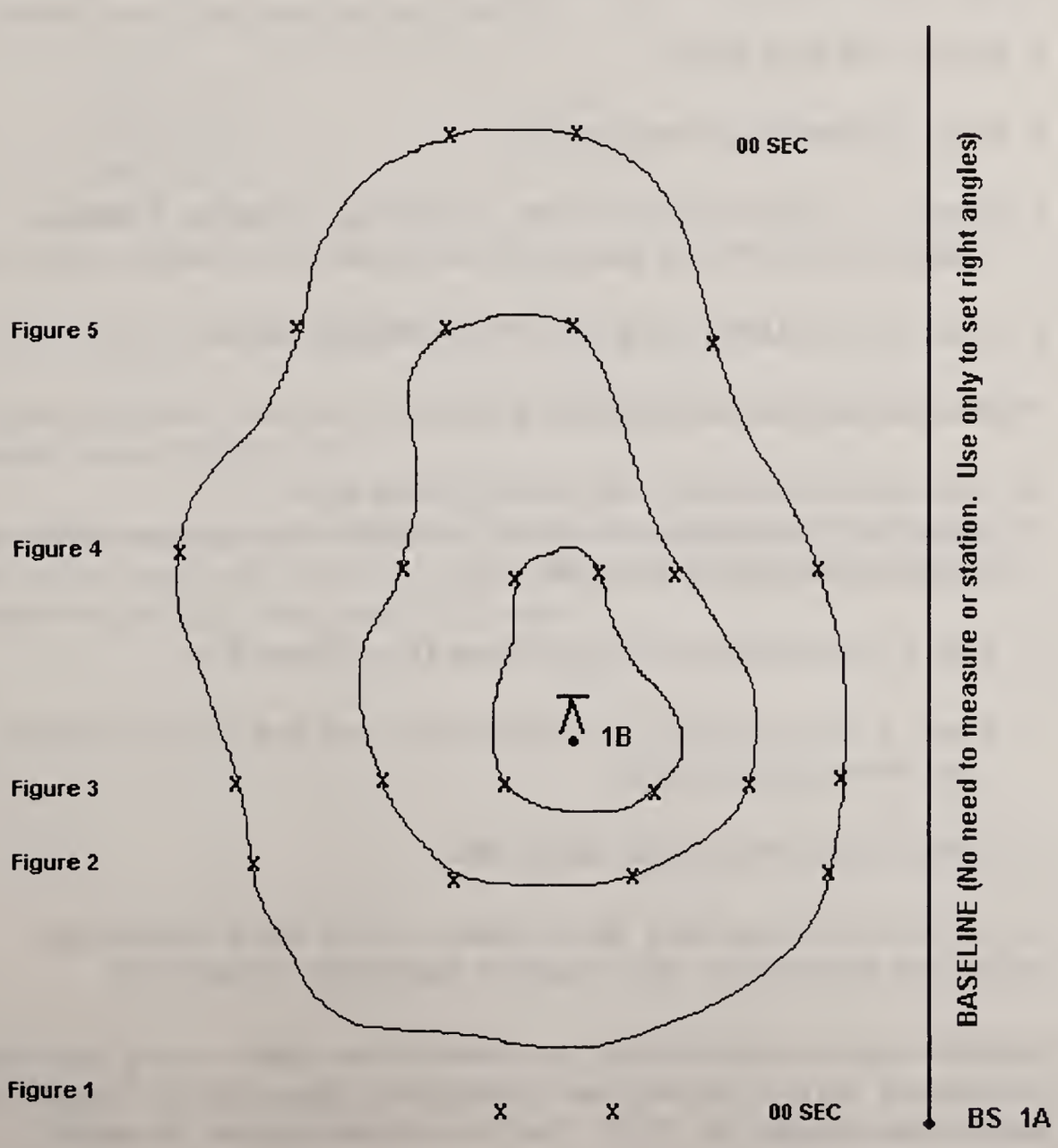
23. Don't panic, it takes it awhile to calculate.

When it's done calculating it will show Pit RPT giving the volume.

Save N .

Now you are finished, and you download to your laptop.

PLAN VIEW - STOCKPILE



To Print CRD List From Survey Office

By Lance Spooner
January 1998

1. At the c: prompt type **Print**

2. When asked Name of list device [PRN] type **LPT1**

3. Now get into Survis Office **CD SURVIS**

4. **SO** You should be at Survis Office Menu

5. Select **Field Data Entry**

6. Select **Existing Data Collection Files**

7. Cursor up to **.CRD** and hit the **F2** key. A list of files will appear to the right. Highlight the CRD file you want to print and **Enter**.

8. Cursor over to **CONST** and down to **Write ASCII Point File**

9. Enter the points you want to print or **A** for all.

10. Now enter your file name. Use your original file name.
    EXAMPLE: File 1012rw, File 1012tr, File 1012tp These are three different files. For one job you would want to use only **1012**.

11. Cursor over to **FILE** and down to **Review Data / Report Files**

12. Cursor down to your **.XYZ** file. **Enter** and you will be able to view your file. If you like what you see, hit **Esc Quit**

13. Cursor down to **Print Data / Report Files**

14. Cursor down to your **.XYZ** file hit **Enter**. Your file should begin printing.

TO MERGE CADD FILES [BE CAREFUL USING WILDCARDS (*)]

Instructions on how to easily merge your individual data collector survey files into one combined file. Be sure you really want to combine the files you select. Typically these files all have the same extension (ie. .XYZ). The * is a wildcard character. Be careful!

In this example we are going to merge all the individual .XYZ files for on a project.

1. Go to a DOS prompt. **C:\>**

2. Go to the directory where the files reside.
   Example: If the files are in a directory called SURVEY type **C:\>CD SURVEY**
   (CD stands for Change Directory)

   Now you should have **C:\>SURVEY.**

3. To see the files type **DIR/P** (DIR lists the files and /P stops the list at each page. Hit Enter to advance listing.)

4. Now to merge files.
   Example: Say the following list of files exists.

   1320TP1.XYZ
   1320TP2.XYZ
   1320TP3.XYZ
   1320TR1.XYZ

5. Use the copy command as follows:

   COPY 1320*.XYZ 1302ALL.XYZ

The * (wildcard) character takes the place of TP1, TP2, TP3 and TR1 and copies all these files into one file named 1320ALL.XYZ.

Try this on backup copies of files to see if it works the way you want before applying it to needed files! You can find out more about how this works by referring to DOS Help Files either in hard copy manuals or type HELP while at the DOS prompt.

HELPFUL HANDOUTS

Handout #	Explanation
1-1	READ ME FIRST - Lithium Battery Instructions & Data Collector Formatting Instructions.
2-1 to 2-16	Sign Cell Libraries - to be used in the data collectors description block to describe signs. Use upper left hand number, example R1.1. See NOTE at top of 2-15 & 2-16 before use.
3-1 to 3-2	Sample Memo and read.me file. This is sent to the District Construction Engineer and to the DI Directory on the CADD Access Server.
4-1 to 4-4	Updating Data Collector Software by Tim Boucher.
5-1 to 5-2	Daily data collection form to help keep track of items for editing and general information.
6-1 to 6-2	Same as #5 in a different format.
7-1	New base line user report.
8-1	Docking station information.
9-1	Battery information.
10-1 to 10-3	New survey protocol.
11-1	File editing information.
12	Preliminary Survey Request Form

Handout #1

READ ME FIRST

Thank you for purchasing the WPI Mcropalm PC/3040V hand-held computer. Before using your PC/3040V, please take a few moments to review the information below.

PC/3040V Backup Battery Installation

Your PC/3040V was packaged and sbipped without the Lithium backup battery connected It is recommended that the Backup Battery be connected only during periods of normal use, and that it be disconnected for extended storage periods (note that disconnecting the Backup Battery will destroy all data on the RAMDISK). This will increase the overall life of the backup battery, which maintains the data on the PC/3040V RAMDISK when the main (NiCd) batteries are not installed or are discharged.

The Backup Battery consists of a small, black enclosure with two leads terminated in a white, 3-pin connector. To install the Backup Battery . in the PC/3040V, follow these steps:

1. Turn the PC/3040V over and unhook the elastic hand-strap from the case.

2. Remove the battery compartment cover by loosening the retaining screw, lifting the bottom edge of the cover, and sliding the cover off..

3. Position the Backup Battery above the slot at the bottom of the battery well with the leads exiting from the lower right comer of the Backup Battery.

4. Press the connector into the receptacle while sliding the Backup Battery into the slot. Make sure that the connector is seated firmy into the receptacle. The Backup Battery is held in place by the battery well ribs and the battery compartment cover.

5. Install the 5 main batteries (NiCd or Alkaline 'A' or 'AA' cells), observing the polarity marked in each battery location.

6. Replace the battery compartment cover and tighten the retaining scew.

7. If you are using NiCd batteries, charge them using the PC/3040V Supercharger or the PCJ3040V Wall Charger, sold separately.

8. The PC/3040V may now be powered on. Refer to the PCI3040V User's Guide for more information on powering on and using the PC/3040V.

Formatting the PC/3040V RAMDISK

Each time the PC/3040V Backup Battery is installed, the RAMDISK (i.e., Drive C) will need to be formatted prior to use. This is accomplished using the FMTSRAM utility on the PC/3040V ROMDISK (i.e., Drive D), as described below-.

1. Power on the PC/3040V. Type "D : <ENTER.>" You should see "D>" on the display.

2. Use the FMTSRAM utility program to format the RAMDISK by typing one of the command lines listed below:

If your PC/3040V is configured with:	Type this command at the "D >" prompt:
1 MEG RAMDISK (2 MEG Total RAM):	"FMTSRAM /64 <ENTER>"
2 MEG RAMDISK (3 MEG Total RAM):	"FMTSRAM /128 <ENTER>"
3 MEG RAMDISK (4 MEG Total RAM):	"FMTSRAM /192 <ENTER>"
4 MEG RAMDISK (5 MEG Total RAM):	"FMTSRAM /256 <ENTER>"
5 MEG RAMDISK (6 MEG Total RAM):	"FMTSRAM /320 <ENTER>"

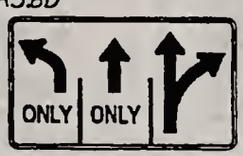
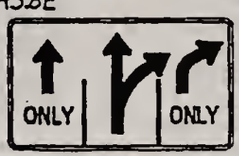
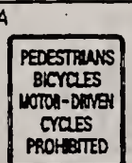
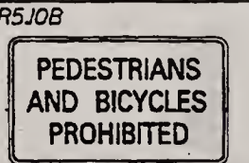
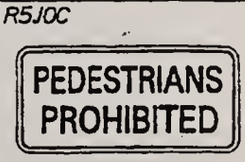
3. If you want the PC/3040V to boot from the RAMDISK, type the following at the "D>" prompt:

COPY AUTOEXEC.BAT C: <ENTER.>
COPY CONFIG.SYS C: <ENTEr,>
<CTL> <ALT> <DEL>

71MC10073-2 8/95

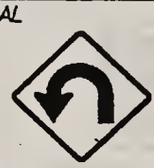
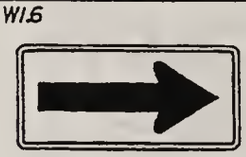
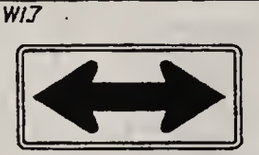
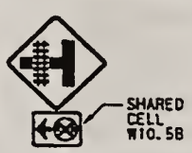
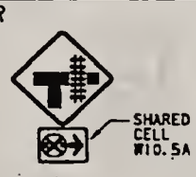
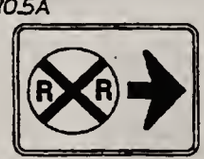
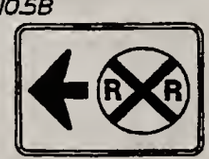
R1.1 STOP	R1.1A STOP	R1.2 YIELD	R1.3 DATA FIELD 4-WAY
R1.4 ALL WAY	R10.1 CROSS ON GREEN LIGHT ONLY	R10.10 LEFT TURN SIGNAL	R10.12 LEFT TURN YIELD ON GREEN
R10.2 CROSS ON WALK SIGNAL ONLY	R10.3 PUSH BUTTON FOR GREEN LIGHT	R10.3A TO CROSS STREET PUSH BUTTON WAIT FOR GREEN LIGHT	R10.4 PUSH BUTTON FOR WALK SIGNAL
R10.4A TO CROSS STREET PUSH BUTTON WAIT FOR WALK SIGNAL	R10.4B PUSH BUTTON FOR	R10.5 LEFT ON ARROW ONLY	R10.6 STOP HERE ON RED
R10.6A STOP HERE ON RED	R10.7 DO NOT BLOCK INTERSECTION	R10.8 USE LANE WITH GREEN ARROW	R10.11A NO TURN ON RED
R10.11B NO TURN ON RED	R11.1 KEEP OFF MEDIAN	R11.2 ROAD CLOSED	R11.3 ROAD CLOSED 50 MILES AHEAD LOCAL TRAFFIC ONLY DATA FIELD
R11.3B BRIDGE OUT 45 MILES AHEAD LOCAL TRAFFIC ONLY DATA FIELD	R11.4 ROAD CLOSED TO THRU TRAFFIC	R12.1 WEIGHT LIMIT 16 TONS DATA FIELD	R12.2 AXLE WEIGHT LIMIT 3 TONS DATA FIELD
R12.3 NO TRUCKS OVER 2500 LBS EMPTY WT DATA FIELD	R12.4 DATA FIELD WEIGHT LIMIT 2 TONS PER AXLE 22 TONS GROSS	R12.5 WEIGHT LIMIT 8 T 22 T 55 T DATA FIELD	R13.1 ALL TRUCKS COMMERCIAL VEHICLES NEXT RIGHT

R13JA ALL TRUCKS COMMERCIAL VEHICLES	R13.2 NONRESIDENT TRUCKS–BUSSES MUST HAVE G.V.W. PERMITS	R14J TRUCK ROUTE	R15J RAIL ROAD CROSSING
R15.2 DATA FIELD 3 TRACKS	R15.3 EXEMPT	R15.5 NO CAMPING	R2J SPEED LIMIT 55 DATA FIELD
R2J1 SPEED CHECKED BY RADAR	R2.2 TRUCKS 55 DATA FIELD	R2.5A REDUCED SPEED AHEAD	R2.5B REDUCED SPEED 55 DATA FIELD
R2.5C SPEED ZONE AHEAD	R2.7D END SPEED ZONE	R3J	R3J0 RESTRICTED LANE AHEAD
R3J1 BUSES AND CAR POOLS ONLY	R3J2 RESTRICTED LANE ENDS	R3J3 RESTRICTED LANE AHEAD	R3J4 BUSES AND 4 RIDER CAR POOLS ONLY
R3J5 RESTRICTED LANE ENDS	R3J6 LANE AHEAD	R3J7 RIGHT LANE ONLY	R3JP NO RIGHT TURN
R3.2	R3.2P NO LEFT TURN	R3.3 NO TURNS	R3.4
R3.4P NO U TURN	R3.5 ONLY	R3.5A ONLY	R3.5B ONLY

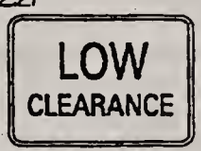
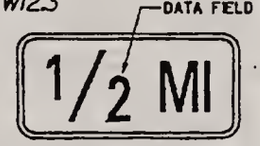
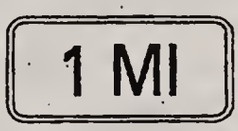
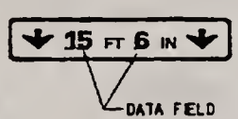
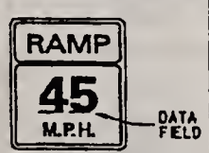
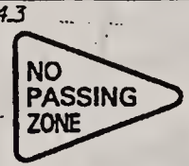
R3.6	R3.6A	R3.7	R3.7R
R3.8	R3.8A	R3.8B	R3.8C
R3.8D 	R3.8E 	R3.9	R3.9A
R3.9B	R3.9C	R3.9D	R4.1
R4.14	R4.2	R4.20	R4.3
R4.4	R4.5	R4.6	R4.7
R4.7A	R4.7B	R4.7P	R4.8
R5.1	R5.10A 	R5.10B 	R5.10C 

R5.1A WRONG WAY	R5.2	R5.3 NO MOTOR VEHICLES	R5.4 COMMERCIAL VEHICLES EXCLUDED
R5.5 VEHICLES WITH LUGS PROHIBITED	R5.6	R6.1L ONE WAY	R6.1R ONE WAY
R6.2R ONE WAY	R6.3 DIVIDED HIGHWAY	R6.3A DIVIDED HIGHWAY	R7.10 NO PARKING OR STOPPING SCHOOL DAYS 8 AM TO 4 PM
R7.107 NO PARKING BUS STOP	R7.10A NO PARKING SCHOOL DAYS	R7.1A NO PARKING ANY TIME	R7.1L NO PARKING ANY TIME
R7.1R NO PARKING ANY TIME	R7.2 NO PARKING 8:30 AM TO 5:30 PM DATA FIELD	R7.200 NO PARKING ANY TIME / ONE HOUR PARKING 9 AM-7 PM DATA FIELD	R7.201 TOW-AWAY ZONE
R7.202 THIS SIDE OF SIGN	R7.2A 8:30 AM TO 5:30 PM	R7.3 NO PARKING	R7.3A NO PARKING HERE TO CORNER
R7.4 NO STANDING ANY TIME	R7.5 ONE HOUR PARKING 9AM-7PM DATA FIELD	R7.5A ONE HOUR PARKING	R7.6 NO PARKING LOADING ZONE
R7.8 RESERVED PARKING	R7.8A NO PARKING BETWEEN SIGNS	R7.9 NO PARKING BIKE LANE	R7.9A BIKE LANE

R7.R NO PARKING BUS STOP	R7107A 	R7108 2 HR PARKING 8:30 AM TO 5:30 PM	R7108A ½ HR PARKING 8:30 AM TO 5:30 PM
R7108B 20 MIN PARKING 8:30 AM TO 5:30 PM	R7201A 	R8.1 NO PARKING ON PAVEMENT	R8.2 NO PARKING EXCEPT ON SHOULDER
R8.3 NO PARKING	R8.3A 	R8.4 EMERGENCY PARKING ONLY	R8.5 NO STOPPING ON PAVEMENT
R8.6 NO STOPPING EXCEPT ON SHOULDER	R8.7 EMERGENCY STOPPING ONLY	R8.8 DO NOT STOP ON TRACKS	R9.1 WALK ON LEFT FACING TRAFFIC
R9.2 CROSS ONLY AT CROSS WALKS	R9.3 NO PEDESTRIAN CROSSING	R9.3A 	R9.3BR USE CROSSWALK
R9.4 NO HITCH HIKING	R9.4A 	R9.5 USE PED SIGNAL	R9.6 YIELD TO PEDS
R9.7 KEEP LEFT RIGHT	R99.1 LITTERING HIGHWAY PROHIBITED $100 FINE	RA.3 ACCESS RESTRICTED	
R2.1C SPEED LIMIT 65 TRUCKS 65	R2.1C1 SPEED LIMIT 55 TRUCKS 60		

DUCK	ELK	MOOSE	SHEEP
W1.1L	W1.1R	W1.2L	W1.2R
W1.3L	W1.3R	W1.4L	W1.4R
W1.5AL 	W1.5AR	W1.5L	W1.5R
W1.6 	W1.7 	W1.8	W10.1
W10.2L 	W10.2R	W10.3L	W10.3R
W10.4L	W10.4R 	W10.5A 	W10.5B 
W11.1	W11.10	W11.2	W11.2A

Handout 2-7

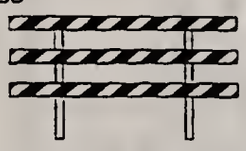
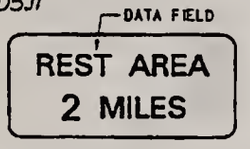
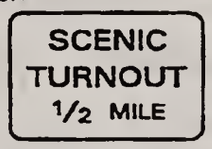
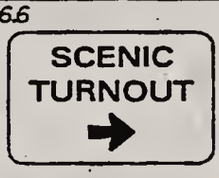
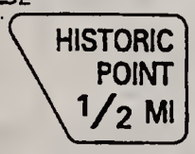
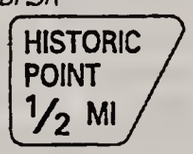
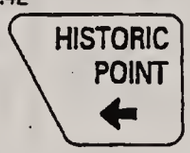
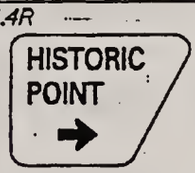
W11.3	W11.3A	W11.3P	W11.4
W11.4A	W11.5	W11.6A	W11.7
W11.8	W11.8A	W11.9	W12.1
W12.2	W12.2P 	W12.3 	W12.3A 
W12.3B	W12.4 	W13.1	W13.2
W13.3 	W14.1	W14.2	W14.3 
W15.1	W21	W22	W23L
W23R	W24	W25	W201

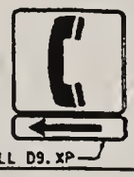
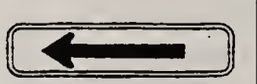
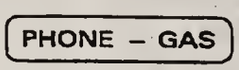
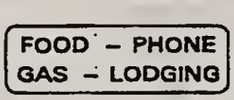
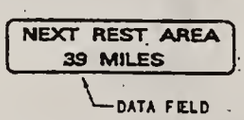
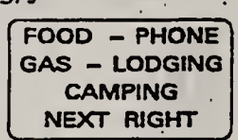
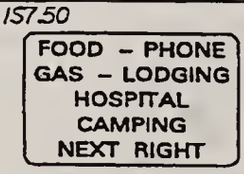
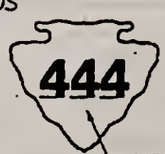
W20J0 EQUIPMENT ENTERING	W20J1 EQUIPMENT CROSSING	W20J2 NO CENTER STRIPE	W20J3
W20.2 DETOUR 1000 FT DATA FIELD	W20.3 STREET CLOSED 1000 FT DATA FIELD	W20.4 ONE LANE ROAD 1000 FT DATA FIELD	W20.5 CENTER LANE CLOSED 1000 FT DATA FIELD
W20.7 FLAGGER 1000 FT DATA FIELD	W20.7A	W20.P3 DATA FIELD 500 FEET	W20.P4 DATA FIELD 1000 FEET
W21J WORKERS	W21JA	W21.2 FRESH OIL	W21.3 ROAD MACHINERY 1000 FT DATA FIELD
W21.4 ROAD WORK 1000 FT DATA FIELD	W21.5 SHOULDER WORK	W21.6 SURVEY CREW	W22J BLASTING ZONE 1000 FT DATA FIELD
W22.2 TURN OFF 2-WAY RADIO	W22.3 END BLASTING ZONE	W3J STOP AHEAD	W3JA
W3.2A	W3.3	W3.3P SIGNAL AHEAD	W4J
W4JP MERGE	W4.2L	W4.2R	W4.3

W5J ROAD NARROWS	W5.2A NARROW BRIDGE	W5.3 ONE LANE BRIDGE	W6J
W6JP DIVIDED HIGHWAY	W6.2	W6.2P DIVIDED HIGHWAY ENDS	W6.3
W6.3P 2-WAY TRAFFIC	W7J	W7JA 6% DATA FIELD	W7.2 USE 2ND GEAR
W7.2A USE LOW GEAR	W7.2B TRUCKS USE LOWER GEAR	W7.3 DATA FIELD 6 % GRADE	W7.3A NEXT 6 MILES DATA FIELD
W7.3B DATA FIELD 8% GRADE 3 MILES DATA FIELD	W7.4 RUNAWAY TRUCK RAMP 5 MILE DATA FIELD	W7.4A RUNAWAY TRUCK RAMP	W7.5
W8J BUMP	W8J0	W8J1 WATCH FOR FALLEN ROCK	W8J1A
W8J2A ICY ~~SPOTS~~ NEXT 10 MI DATA FIELD	W8J2B WATCH FOR ~~ICE~~ ON BRIDGE	W8.2 DIP	W8.3 PAVEMENT ENDS
W8.3A NARROW BRIDGE	W8.4 SOFT SHOULDER	W8.5	W8.6 TRUCK CROSSING

Handout 2-10

W8.6A	W8.7	W8.8	W8.9
W8.9A	W9.1L	W9.1R	W9.2L
W9.2R			

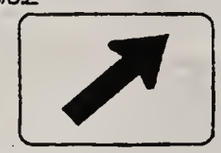
B3 	BAR.3	D10.1	D10.2
D10.3	D4.1	D4.2	D5.1
D5.1I 	D5.2L	D5.2R	D5.5
D5.5A	D5.5B	D6.4 	D6.6 
D7.3L 	D7.3R 	D7.4L 	D7.4R 
D7.5L	D7.5R	D7.6L	D7.6R
D8.1	D8.2	D8.2A	D8.3
D9.1OL	D9.1OR	D9.12L	D9.12R

D9.1L  SHARED CELL D9.XP	D9.1R SHARED CELL D9.XP	D9.2 SHARED CELL D9.XP	D9.20 SHARED CELL D9.XP
D9.3 SHARED CELL D9.XP	D9.3AL SHARED CELL D9.XP	D9.3AR SHARED CELL D9.XP	D9.4
D9.4B	D9.5	D9.6A	D9.7
D9.8	D9.9	D9.XP 	I.5 SHARED CELL D9.XP
I.S1.1 	I.S2.1 	I.S3.1	I.S4.1
I.S6.2 	I.S6.4	I.S6.5	I.S7.1 
I.S7.5.0 	M.I.1	M.I.1.0	M.I.1.0.S 
M.I.1.1	M.I.1.2	M.I.2	M.I.4.2

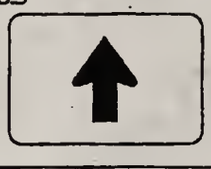
M1.4.3
DATA FIELD
265
M1.4A2
DATA FIELD
40
M1.4A3
DATA FIELD
256
M1.5.2
MONTANA
35
DATA FIELD
M1.5.3
MONTANA
200
DATA FIELD
M1.6
DATA FIELD
LEWIS & CLARK
44
COUNTY
DATA FIELD
M1.7
DATA FIELD
22
National Forest
M1.8
22
DATA FIELD
M1.9
DATA FIELD
444
M2.1
JCT
M2.2
JUNCTION
93
251
DATA FIELD
M3.1
NORTH
M3.2
EAST
M3.3
SOUTH
M3.4
WEST
M4.1
ALTERNATE
M4.1.1L
DETOUR
M4.1.1R
DETOUR
M4.1.1
BEGIN
M4.1.2
END
M4.1.3
TO
M4.1A
ALT
M4.2
BY-PASS
M4.3
BUSINESS
M4.4
TRUCK
M4.5
TO
M4.6
END
M4.7
TEMPORARY
M4.8
DETOUR
M4.9
DETOUR
M5.1
M5.2

M6J

M6.2

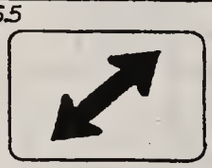


M6.3

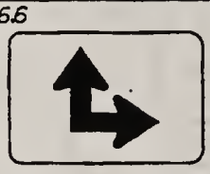


M6.4

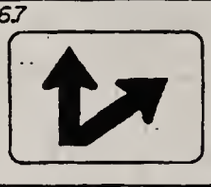
M6.5



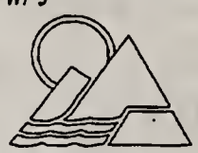
M6.6



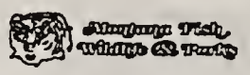
M6.7



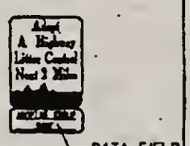
MFWPJ



MFWP.2



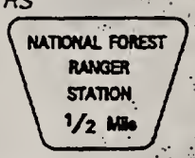
N7J



NFLOGO

National Forest

NFRS



OM.3L

OM.3R

RS.000

RS.054

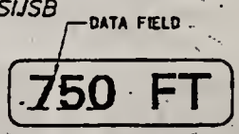
RS.063

SIJ

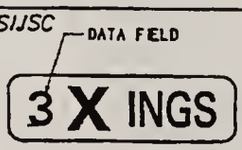
SIJSA

1 BLOCK

SIJSB



SIJSC



S2J

S3J

S4J

8:30 AM
TO 5:30 PM

S4.2

WHEN
CHILDREN
ARE PRESENT

S4.3

SCHOOL

S4.4

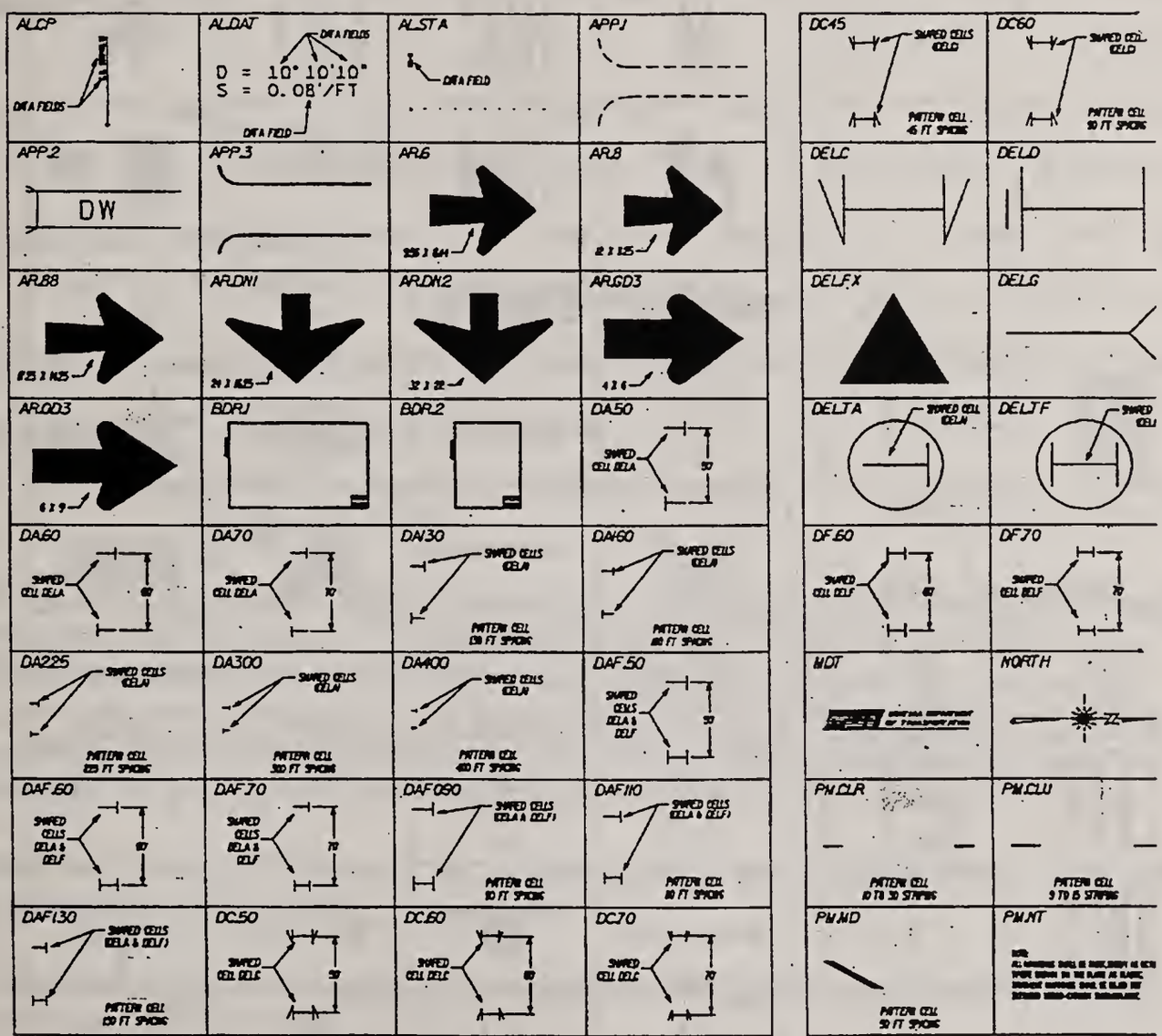
WHEN
FLASHING

S5J

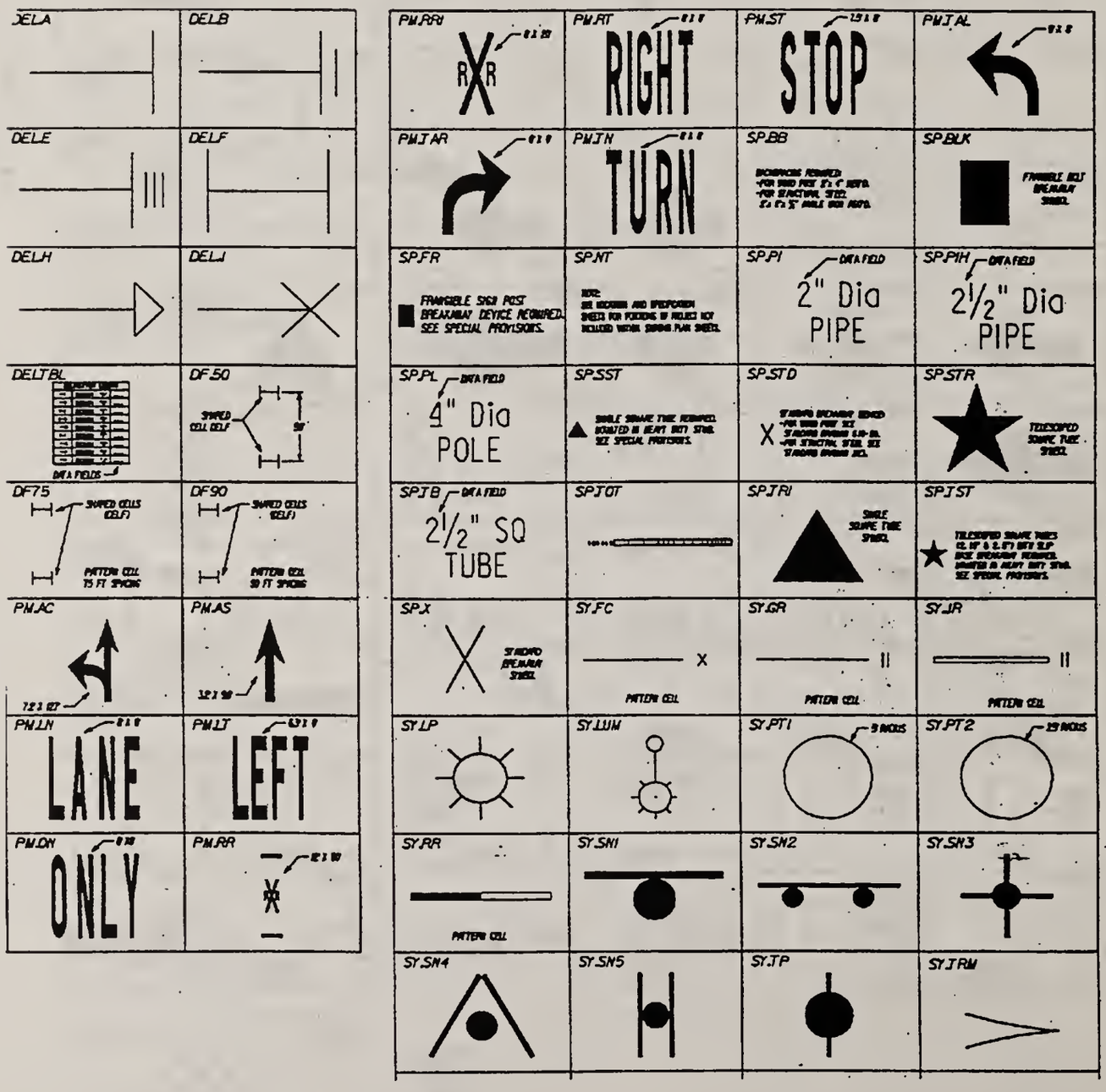
X3.2

X3.3

NOTE: Feature Codes include many of these! Implementation of standards for cell libraries will soon make ID number invalid.



NOTE: Feature Codes include many of these! Implementation of standards for cell libraries will soon make ID number invalid.



Handout 2-16

Handout 3-1

Montana Department of Transportation
Helena, Montana 59620

MEMORANDUM

To: Cal Frank, P.E.
District Construction Engineer

From: Ray Sacks
Engineering Project Manager

Date: August 20, 1997

Subject: STPHS 0002(219)
Traffic Improvements - Helena
Control No. 3075

The survey data requested was processed and completed through teamwork from the Photgrammetry/Survey Unit, Traffic/Safety Unit and our Field Crew. The raw data from the Data Collector was edited and converted to Surface Coordinates, then the .XYZ files were used to create the Filed Design file. This design file and all the other files were transferred to the DI subdirectory on the CADD Access Server. This can then be accessed by the appropriate Units to complete the design of the Project or for review.

Attached is the 3075read.me file, which is also in the DI subdirectory. It is an explanation of all the fiies.

I would like to voice my appreciation for the help we received from Dave Davis, Craig Brown and Sandy Stiffler.

RLS/PJ/pj
CC: FILE 3075-3

SAMPLE READ.ME FILE

Handout 3-2

NOTE: This read.me file gets saved as 3075READ.ME along with the Project Files in the DI subdirectory on the CADD Access Server.

Control Number: 3075
Project Number: STPHS 0002(219)
Project Name: East Helena Traffic Improvements
Date: August 20, 1997
Survey Contact Joe Smith

The f ollowing files have been downloaded to DI subdirectory:

1. 3075A.RAW-ASCII file-first area of Topog. survey
2. 3075BED.RAW-ASCII file-second area of Topog. survey
3. 3075CED.RAW-ASCII file- third area of Topog. survey
4. 3075D,RAW-ASCII file-forth area of Topog. survey
5. 3075E.RAW-ASCII file-fifth area of Topog. survey
6. 3075F.RAW-ASCII file-sixth area of Topog. survey
7. 3 075G.RAW-ASCII file-seventh area of Topog. survey
8. 3075H.RAW-ASCII file-eighth area of Topog. survey
9. 3075ALL.RAW-ASCII file-all the Topog.. files merged into this file
10. 3075ALL.RPT-ASCII file-the report file generated from 3075ALL.RAW
11. 3075ALL.XYZ-ASCII file-the coordinates for the Topog. using 3075MAS.CRD as the coordinate file for the control points used, this CRD file was converted to the surface coordinate system.
12. 3075ED2.ORG-ASCII file-original unedited control traverse on state plane coordinate system
13. 3075ED2.RAW-ASCII file-edited control traverse on state plane coordinate system
14. 3075ED2.RPT-ASCII file-report file generated frorii 3075ED2.RAW
15. 3075ROT.XYZ-ASCII file-control traverse coordinates generated from rotating 3075ED2.XYZ to a geodetic bearing, 3075ED2.XYZ was deleted.
16. 3075MAS.CRD-ASCII file-the surface coordinate file used to generate the final coordinates for 3075ALL.XYZ
17. 3075TPOI.FLD-MicroStation 2-D design file-design file generated from 3075A-LL.XYZ, this is on surface coordinates

The raw data was converted from State Plane (Grid) Coordinates to Surface Coordinates by processing the raw data with a correction factor of 1.00000, then rotating the . XYZ file about fixed point 1B an angle of -01 46' 44.1" (counter clockwise).
A scale factor does appear in the raw data but the data was processed with a scale factor of 1.0000.

The basis of bearing was determined by Geodetic derived bearing between points 100CC and 100YY.

Only files 3075TP01.FLD, 3075ALL.RPT, 3075ED2.RPT, 3075ROT.XYZ and 3075ALL.XYZ should be required by Traffic/Safety Bureau. These files are in the Local Metric Coordinate System.

TO ALL DISTRICT PERSONNEL: **Handout #4-1**
SUBJECT: Data Collector Software

NOTE: Do not attempt to use File Manager or Windows Explorer when transferring files between a computer and a data collector. The C: drive on the data collector may get corrupted, requiring the C: drive on the data collector to be reformatted using the FMTSRAM command and causing you to lose all of the files on the C: drive on the data collector (this includes your survey data files). Please call Tim Boucher in ISB at 444-7269 if you have any questions about this. **WE REPEAT - - - NEVER use File Manager or Windows Explorer to transfer files between ca computer and a Data Collector or you could lose all of your Survey Data Files on the Data Collector!!!**

Currently, you **CAN NOT** transfer files between a computer running Windows NT and a data collector! You can tansfer files between a computer running Windows 95 and a data collector.

The first step is to obtain versions of the Data Collection Software. You can receive the updated versions of the software on a diskette from Helena or you can copy them from the "O:\" drive under the Survey Directory directly to a diskette in you PC. The next step is to copy the Office and Field Versions of the Data Collection Software to a PC. This is accomplished using the updated diskettes as follows:

At the C:\> prompt, type the following:

CD C:\SURVIS\SVFLD (Hit the ENTER key)

This will put you in the directory where you want to copy the field versions files to . . .
Insert the diskette containing the updated version of the Field Software.

At the C:\SURVIS\SVFLD> prompt, type the following:

A: (Hit the ENTER key)

Then at the A:\> prompt type the following:

COPY *.* C: (Hit the ENTER key)

This will copy the Filed Version Software from the diskette into the C:\SURVIS\SVFLD directory.
Now you can copy the Office Version of the Data Collection Software as follows:
At the A:\> prompt type the following:

C: (Hit the ENTER key)

At the C:\SURVIS\SVFLD\ prompt, type the following:

Insert the diskette containing the updated version of the Office Software.

At the C:\SURVIS> prompt, type the following:

A: (Hit the ENTER key)

Then at the A:\> prompt, type the following:

COPY *.* C: (Hit the ENTER key)

This will copy the Office Version Software from the diskette into the C:\SURVIS directory.

Loading Field Version Software in the Data Collector

Be sure that the Data Collector cable is connected to an open communications port on the laptop or PC. . . COMM PORT 1 or 2.

NOTE: Each time the Lithium backup battery is installed the RAMDISK will need to be formatted prior to installing software. To format the RAMDISK see the "READ ME FIRST" instructions included with the Data Collector. At the "D:\>" prompt (To go to the D:\> prompt, type D: and hit the ENTER key.) the command for a 2 MEG RAMDISK should be entered. The command at the "D:\>" prompt is as follows:

FMTSRAM /128 (Hit the ENTER key)

NOTE: To begin loading the Data Collection Software files, enter the following information at the Data Collector C:\> prompt (To go to the C:\> prompt, type C: and hit the ENTER key.):

PCLINK (Hit the ENTER key)

The handheld Data Collector C: drive is now associated with the E: drive on the PC. The following will appear on the Data Collector screen:

```
This Computer (PC)          Other Computer (MicroPalm)
   (Client)                    (Server)          }
-------------------------   ------------------------------------} shows up on the
  D:  equals                A:                          } data collector
  E:  equals                  C:                          } screen
  F:  equals                  D:                          }
```

Then on the PC/Laptop enter the follwoing two commands:

C: (Hit the ENTER key)

CD C:\SURVIS (Hit the ENTER key)

Then at the C:\SURVIS> prompt enter the following on the PC/Laptop:

INTERLINK

The following will appear on the PC/Laptop screen:

```
PORT=COM2

This Computer (PC)          Other Computer (MicroPalm)
   (Client)                    (Server)          }
-------------------------   ------------------------------------} shows up on the
  D:  equals                  A:                          } PC screen
  E:  equals                  C:                          }
  F:  equals                  D:                          }
```

Insert the Field Version diskette into the PC/Laptop diskette drive.

At the C:SURVIS> prompt on the PC/Laptop type the following:

A: (Hit the ENTER key)

Then at the A:\> prompt on the PC/Laptop enter the following:

COPY *.* E: (Hit the ENTER key)

The files will now be copied from the Field diskette to the Data Collector.

The following will appear of the PC screen:

LVL.EXE	}	
STAR.EXE	}	
FLDMNU.EXE	}	
SFG.EXE	}	
SDC.EXE	}	The Data Collection Software
SF.BAT	}	files will come up on the PC
AUTOEXEC.BAT	}	
PCODES.FF	}	
LVL.HLP	}	
SDC.PAR	}	
CRDD2CRD.EXE	}	

(There will be 11 files copied to the Data Collector.)

A:\> } will appear on the PC screen

NOTE: When all the files have been copied Go to the Data Collector Keyboard and hit the <ALT> and <F4> keys.

Then make sure the Data Collector is at the C:\> prompt (To go to the C:\> prompt type "C:" and hit the ENTER key.) and enter the following on the Data Collector screen to check to see if the transfer was OK:

DIR (Hit the ENTER key)

You should now see the 11 Data Collection Field Version Software files listed on the Data Collector screen.

HLN CONST BR . . .

PROJECT No _____ DESIGNATION _____

PERSONNEL _____ DATE _____

Handout 5-1 FRONT

SETUP 1					
TEMP	PRESS	PPM	WEATHER		FILE NAME:
PT ID	PT POS	Y CRD (N)	X CRD (E)	ELEV	
					OCC HT:
					BS HT:
					PICKET 1 HT:
					PICKET 2 HT:
					PICKET 3 HT:
					PICKET 4 HT:

SETUP 2					
TEMP	PRESS	PPM	WEATHER		FILE NAME:
PT ID	PT POS	Y CRD (N)	X CRD (E)	ELEV	
					OCC HT:
					BS HT:
					PICKET 1 HT:
					PICKET 2 HT:
					PICKET 3 HT:
					PICKET 4 HT:

Handout 5-2 BACK

FEATURE CODES	GROUP No	SKETCH

Items to be edited and general comments

PROJECT NO. _____ DESIGNATION _____

PERSONNEL _____ DATE _____

PT. ID.	PT. POS.	X. COORD.	Y COORD.	ELEV.	FILE NAME:
					.CRD FILE USED
					CREW
					25.4mm = 1 in
					(F-32) / 1.8 = C
					(C x 9/5) + 32 = F
					CN
					TEMP
					PRESSURE
					PPM
					WEATHER
					ZENITH ANGLE CHECK
					HI
					BS MIRROR HT
					PICKET HT
					PICKET HT
					PICKET HT
					PICKET HT

Handout 6-1 FRONT

Handout 6-2 BACK

FEATURE CODES	GROUP #	COMMENTS

ITEMS NEEDING EDITING

COMMENTS

Handout 7-1

BASE LINE USER REPORT

BASE LINE NAME _____ COUNTY _____

INSTRUMENT OWNER _____ DATE _____

CREW _____ WEATHER _____

PHONE _____

INSTRUMENT	REFLECTOR
MAKE _____	_____
MODEL _____	_____
SERIAL NUMBER _____	CONSTANT _____
STANDARD DEVIATION (_____ mm + _____ ppm)	X NGS MARK-MARK DISTANCE X 2 = Allowable Tolerance

NOTE: REFER TO YOUR INSTRUMENT MANUAL FOR YOUR SPECIFIC STANDARD DEVIATION

MARK TO MARK

Instrument Station / Reflector Station	0 M to 150 M	0 M to 430 M	0 M to 1400 M	150 M to 430 M	150 M to 1400 M	430 M to 1400 M
Temperature / Pressure	/	/	/	/	/	/
PPM						
Height of Instrument (1)	FT	FT	FT	FT	FT	FT
	M	M	M	M	M	M
Height of Reflector (1)	FT	FT	FT	FT	FT	FT
	M	M	M	M	M	M
DH=HI-HS	M	M	M	M	M	M
X=Measured Distance (Record Five Readings) Slope Distances	M M M M M	M M M M M	M M M M M	M M M M M	M M M M M	M M M M M
Average Measured Distance	M	M	M	M	M	M
Measured Distance in Feet (2)	FT	FT	FT	FT	FT	FT
Observed Mark to Mark Distance = $\sqrt{X^2 - DH^2}$	M	M	M	M	M	M
NGS Mark to Mark	M	M	M	M	M	M
Difference	M	M	M	M	M	M
Allowable Tolerance	M	M	M	M	M	M
NOTES:	Pass/Fail	Pass/Fail	Pass/Fail	Pass/Fail	Pass/Fail	Pass/Fail

(1) Make all measurements including HI and HS in meters except for one slope distance in feet.
(2) This distance is for a check only and should not be used to reduce the measured distance to Mark to Mark
Return copy to: Montana Department of Transportation, 2701 Prospect, Helena, MT 59620
Attn: Photogrammetry and Survey Section.

MICRO PALM COMPUTERS

PC/3042 - PC/3040V SUPERCHARGER
USER NOTES

The PC/3040V Supercharger will have model # 10415 and the first two characters of serial number suffix = 'SV' (= 'SR' for 3042).

Getting Started

When first placing the hand-held in the cradle, the green 'CHARGE READY' light will begin flashing immediately indicating a rapid charge cycle has begun. At the end of this charging cycle (as much as 60 minutes for a completely "dead" set of batteries), the "CHARGE READY" light will remain on indicating that the battery Ready Mode has started. This is a maintenance mode or trickle charge to keep the batteries at a full charge. Once the Ready Mode has been reached, the batteries are fully charged, and the hand-held computer may be removed from the cradle.

Should the unit be removed from the cradle, the red FAULT light will light briefly. If, for any reason, the unit's connection to the cradle has been disrupted, the red FAULT light will light and remain lit until the RESET button is pressed or the unit has been removed completely from the cradle and then replaced.

If the red FAULT light becomes lit during a charge cycle, remove the unit and verify that batteries are installed, that they are Nickel Cadmium, and that they are oriented correctly. If all these conditions are met, then set unit back in charger and try charging again. If the FAULT occurs again, replace the batteries one at a time until charge cycle functions normally.

WARNINGS

1. **DO NOT ATTEMPT TO CHARGE ALKALINE BATTERIES.**
2. Do not repeatedly press the RESET switch after the batteries have been fully charged. This may cause overcharging which damages batteries.
3. After removing a hand-held computer from the cradle, it should not be reloaded into the cradle again for at least 30 seconds. Otherwise, the Supercharger will reinitialize the charge cycle.
4. Do not attempt to charge a hand-held computer that does not have Nickel Cadmium batteries installed.

HARDWARE MAINTENANCE

The MicroPalm data collectors are shock resistant, dustproof, operate between the temperature ranges of -15° F to 100° and are environmentally sealed to prevent moisture (waterproof). All these environmental features can be abused. Normal handling and use of these data collectors by MDT personnel is expected. The data collectors should be placed in a soft vinyl hand carrying case when the data collectors are stored for long periods of time.

Three interlinking cables are supplied with each data collector to transmit data between the data collector, the surveying instrument, a personal computer and docking station (super charging unit). One of these cables transmits data between the surveying instrument and the data collector. Another cable transmits data between the data collector and a personal computer. A third cable transmits data between the docking station (super charging unit) and a personal computer.

POWER MANAGEMENT SYSTEM

(Batteries)

Two types of batteries can be used in the MicroPalm 3040V data collector to provide the main power source. The NiCad (series 1200 mAh, 1400 mAh or 1800 mAh) or the nickel metal hydride (series 1800 mAh) batteries are designated as the primary power source for the MicroPalm data collectors. Only five of the same make and series of battery should be used. Don't mix brands of batteries and don't mix different series of batteries together. The NiCad and nickel metal hydrite batteries are to be charged in the MicroPalm charging docking stations (super chargers). The data collectors can remain connected to the docking station and the batteries will continue to charged until the data collector is needed for use. The batteries can be completely charged in less than two (2) hours and will operate the data collector from 8-12 hours. The data collector can be powered from a 12-volt DC power source even while the data collector is operating. AC power adapters are available that plug into the cigarette lighter receptacle (make sure the vehicle is running) and can provide power to the MicroPalm docking stations (superchangers). The nickel metal hydride batteries (green color batteries) have no "memory" so they don't lose capacity like the NiCad batteries when regularly recharged before a full charge has been used. The NMH batteries can be recharged about 500 times. When any of the batteries deliver less than 6-8 hours of service they should be replaced with new batteries. A data retention system is powered by an alternate 3.6 V high energy Tadiran brand lithium battery. This is a very expensive battery (cost about $30 each) so when the data collectors are not used for long periods of time (more than three weeks) the five main source batteries can be removed and the alternate lithium must be removed. The data collectors should be stored inside the soft carrying case with velcro flap closure and placed inside the hard bound Jensen carrying case (with all power cords and other accessories). All types of "dead" batteries shall be disposed of by following the warning label on each battery or by following the environmental disposal rules for the particular type of battery.

MDT's New Surveying Protocol

Handout 10-1

In moving to the Data Collector/SurVis software surveying procedure, the department will need to make a few changes and come up with a few decisions. Two teams were put together to address the software and the hardware concerns of this new surveying procedure. There are questions to be answered that were generated by field personnel, by administrative personnel and by the two teams. This paper will address some of these questions and give some possible solutions.

Crew Sizes, Positions and Responsibilities

The crew size will not change in numbers but it will change the standard positions. The crew size can vary from as small as two (2) persons to as large as five (5) persons. A breakdown of the various sizes and positions is as follows:

1. One (1) person running the total station/data collector and one (1) person in the field taking data readings with the mirror.
2. One (1) person running the total station/data collector and two (2) persons in the field taking data readings with the mirror.
3. Two (2) persons running the total station/data collector and two (2) persons in the field taking data readings with the mirror.
4. One (1) person running the total station/data collector and three (3) persons in the field taking data readings with the mirror.
5. Two (2) persons running the total station/data collector and three (3) persons in the field taking data readings with the mirror.

When the crew is small, like in the first two examples, the data collection is slow but effective for the crew size. When the crew size is larger, like in the last three examples, the data collection appears to be most efficient when two persons are running the total station/data collector. Efficiency will vary from crew to crew, therefore the size of the crew and their positions should be left up to each Engineering Project Manager.

One member of the crew will be responsible for down loading the data from the data collector to the laptop or PC and creating a .ORGfile. That person will also be responsible for verifying each day's data by using the office version of the SurVis software and the viewer software. This way any errors found in the RAW file can be taken care of immediately while that days work is still fresh in the mind's of the crew. Almost all of the editing of errors will be done in the RAW file. These procedures will require knowledge of the data collector, the laptop or PC, the SurVis software, WordPerfect v6.1 for Windows, the viewer software and simple DOS commands. Training will be needed for the crews to get the new procedures up and running and to achieve efficiency.

Data Collection

Surveying with the total station/data collector will require the use of new procedures similar to that of a radial survey. The survey will consist of data readings taken along the break lines paralleling the centerline as opposed to data readings taken perpendicular to the centerline. When collecting data readings, it is best to collect the readings for alignment, topography and utilities, etc. at separate times, thus eliminating some confusion. There are several reasons for collecting the data readings at separate times. First, there are fewer feature codes to deal with at any one time. Second, some feature codes contain an auto line feature that automatically connects consecutive data readings of the same feature. Third, it will make it easier for the person editing the RAW file if like features are collected sequentially. Last, it will be easier for the person(s) collecting the data readings along the break lines.

Running in center line will no longer be necessary on reconstruction jobs, since coordinate surveying is independent of stations and offsets. This will greatly reduce the time needed for a preliminary survey. However, the existing control points will need to be tied to the control traverse to maintain consistency. A determination has not been reached as how the department will handle overlay projects.

When collecting data the crews must keep in mind how the data collector organizes the information. It is pertinent that the data readings along an alignment be taken in a sequential order. The SurVis software uses a special command that connects data points of the same feature. If the data readings are taken out of order, the lines connecting the points will be in disarray.

The crews will need to use some specific commands in the data collector when collecting data readings for topography. Such as when the crews are taking data readings for large objects, the data collector has a command that reads the angle to the object first and then reads the distance second. This command will be required for most posts, poles, trees, etc. When taking data readings for signs, design has a special request. The crews will use the above procedure for the post(s), but they will need to take an additional reading in front of the sign to show the direction the sign is facing.

Additional Cross-sections

Cross-sections will be needed as a check (quality control) for the total station/data collector and will most likely be needed for pipe quantities. Both the total station/data collector and the level & rod can be used for these checks and quantities.

The RAW File

Almost all modifications to the collected data will be in the RAW file, but only after a LGL file is created. A .ORGfile is a copy of the RAW file in its original, unaltered form. The modifications to the RAW file will require knowledge of surveying, WordPerfect v6.1 for Windows and the RAW file format. After the RAW file has been edited for errors or corrections, the RAW file can be loaded into the SurVis software on the laptop or PC for processing. If any corrections or errors still exist, they will be edited in the RAW file.

Once the survey is complete and the RAW file is free of errors, a DGN file will be created by the field personnel and sent to the "Lead Agency" for the design process.

File Management

There will need to be a file management protocol developed to deal with the file names and extensions. One idea is as follows:

	File Name	Extensions
Preliminary Surveys:	####PE	.RAW, .ORG, .XYZ, .RPT, .DGN, .TXT
Construction:	####CE	.FLD , .ORG
	####****	.XYZ

Note: (The TXT file will contain information about the project, such as the Project Number, the Project Name, the Project Control Number and a brief description about the scope of work.)
Note: The number (#) symbols will be replaced by the four digit control number.
Note: The asteria (*) symbols will be replaced by a two to four character abbreviations.

The initial files sent from Helena will be the TXT file and a XYZ file containing any existing control points. Then the file names will be set by the "Lead Agency".

The XYZ files used for construction, sent to the field survey crews by design, can be broken down into the following ten (10) categories:

alignment (ALGN), right-of-way (ROW), other agency works (OTHR), hydraulics (HYD), utilities (UTIL), signing (SIGN), striping/pavement markings (STRP), guard rail (GR), control traverse ties (TIES) and miscellaneous (MISC).

Each of the ten (10) XYZ files should contain the appropriate data consisting of a Point ID number (sequential for each feature), Northing and Easting (accurate to the ten-thousandths), Elevation (accurate to the thousandths) and a Description (containing an ID, a Station and an Alignment Reference). Each XYZ file should also contain the data for the Control Traverse, since only one (1) file can be loaded into the SurVis software at any one time.

MONTANA DEPT. OF TRANSPORTATION
DATA COLLECTOR FILE EDITING

Handout 11-1

***.RAW* FILE**

Download the .RAW files to the laptop or the PC into a directory where you can find them again. These are ASCII text files so you can look at them in your DOS editor or in **NOTEPAD.** If the files are very large, NOTEPAD will not hold them. Probably the best place to edit these files is in **WordPerfect**. WordPerfect will handle the large files and is an easy place see what you're doing.

When these files come out of the Data Collector, they are in a specific format with Command lines and Data lines. The processor is looking for this format so you have to be careful what and how much editing you do. In the .raw file, the Command lines are shown like:

TRAVERSE
_OCCUPY_PNT_
SIDESHOT
COMMENT
etc.

When processing, the software will be looking for these commands and then taking the data following them to carry out the function, e.g., _OCCUPY_PNT_ the software will look for your Backsight and Occupied point information; coordinates, elev., heights, feature code, and description.

A good place to see if there are any problems in the .raw file is to process it and create a .XYZ file and a .RPT file. If there is something goofy in the ,raw file, there will be lines in the .RPT file which says **UNKNOWN OPERATION**. Look for the point number it is close to and go into the .RAW file to fix it. It won't tell you what the problem is but will show you where it is.

There can be a lot of problems created if the editing is not done properly. Things like spaces or punctuation will cause problems if they're entered in the wrong places. Don't delete things out of the .raw file unless you're absolutely sure you don't want it in there.

The .RAW file is a text file that you can add data to as long as you follow the same format as the rest of the file. Turn on the **SHOW**(carriage return symbol) in the VIEW menu. This will show if you have any extra spaces that shouldn't be there.

Ultimately, the best way to edit the .raw file is to not have any editing. But that is not going to happen. Most of the editing will be changes to feature codes and target heights. Most everything else should be pretty clean.

Handout 12

PRELIMINARY SURVEY REQUEST

PROJECT NO._____ Jan 23,1997
CONTROL NO. _____
WORK TYPE . _____

AERIAL SURVEY CONSIDERATIONS.

AERIAL ☐ yes ☐ no
comments:_____
_____

Photogrammetry to Provide:

☐ 1) **Digital Terrain Model** (includes Geopak Mapping requirements: Ground shots, Spot elevs. Break lines, Planimetric features, Strip map)
☐ **Specify Corridor width** _____
comments:_____
_____

☐ 2) **Cross Sections** (special request; independent of DTM)
comments:_____
_____

☐ 3) **Contours** (special request; independent of DTM)
comments:_____
_____
☐ a) 0.5m interval (Specify Contour intervals required)
☐ b) 1.0m interval
☐ c) 2.0m interval

Ortho-photos ☐ yes ☐ no
comments:_____
_____

Hydraulic requirements.
(To be completed during/or after PFR) *
comments:_____
_____
_____
_____

*NOTE: (Include aerial coverage limits. Also include cross-section location sketch from 7.5 minute quad or aerial photograph as appropriate.)

PROJECT NO._____
CONTROL NO. _____
WORK TYPE . _____

FIELD SURVEY CONSIDERATIONS

CONTACT PERSON (Helena):_____

Field survey to provide:

comments:_____

_____

Control Survey

Level Datum Selection:

- ☐ Assumed
- ☐ As Built
- ☐ NAVD 1988

Horizontal datum (x,y)

- ☐ 1) State Plane Coordinates ☐ G.P.S.
- ☐ 2) Local datum (i.e.10,000 10,000)

Basis of Bearing

☐ Solar ☐ As built ☐ other_____

comments:_____

☐ **1) Digital Terrain Model** (includes Geopak Mapping requirements: Ground shots, Spot elevs. Break lines, Planimetric features, Strip map, inverts etc.)

☐ **Specify Corridor width** _____

comments:_____

_____

☐ **2) Alignment/Cross Sections** (special request; independent of DTM ,staked, etc.)

comments:_____

_____

☐ **3) Utilities**

☐ **Locate all utilities**

comments/exceptions:_____

REQUIREMENTS Utility/other	LOCATION	SURVEY (Depth/height)
Gas	_____	_____
Water	_____	_____
Power	_____	_____
Sanitary Sewer	_____	_____
Telephone	_____	_____
Fiber Optics	_____	_____
_____	_____	_____
_____	_____	_____

NOTE: Please obtain any other utility not specifically identified above.

☐ **4) Existing Culvert Survey** (xyz, size, length, invert)

☐ **5) Supplemental Photo Mapping**
(Field check photogrammetric mapping, Check cross sections, map editing, pick up items) p 5-24 Survey manual

Right of Way Ties:
☐ Section corners
☐ Tie all Found R/W monuments
☐ Property corners & Other required ties (Identified by R/W after receipt of PFR REPORT)
(R/W will supply the specific requests for which entities to tie, this will take approximately 30-60 days after receipt of the PFR report.)
comments:_____
_____

☐ **Soil Survey** **(Includes Corrosive soil report, pipe condition, R-values)**.

SPECIAL HYDRAULIC CONSIDERATIONS: (Refer to Chapter 10 Survey Manual)
CONTACT PERSON _____

I. WATERWAYS:

Existing Bridge Site Survey ☐ yes ☐ no
Location:_____
Hyd-1: Section required- 1 2 3 4 5 6 7 8 All
River Cross-sections Location & width:_____
Contour mapping [extent, intervals] : _____
Special Requirements: _____
_____
_____

Existing Culvert Site Survey ☐ yes ☐ no (Hyd-1 not required when photo mapping is available.)
Location: _____
☐ length ☐ invert elevations
Hyd-1: Section required- 1 2 3 4 5 6 7 8 All
Special Requirements: _____
_____
_____

II. IRRIGATION SURVEY- ☐ yes ☐ no

Location: _____

Hyd-1: Section required- 1 2 3 4 5 6 7 8 All

Special Requirements: _____

_____

_____

III. URBAN SURVEY- ☐ yes ☐ no

Location: _____

Contour mapping [extent, intervals] : _____

Storm drain Outfall/location: _____

Special Requirements: _____

_____

_____

IV. Additional Hydraulic Survey Requirements: _____

_____

_____

_____

_____

SURVEY REQUEST FORM:

INTENT: This form is intended for use during the Preliminary Field Review and will be incorporated into the PFR Report to help clarify the survey needs for a specific project.

Please comment on the **context** of this preliminary document.

Please return to Blair Nordhagen
Missoula Road Design 6239

Table of Contents

Chapter Nine — Construction Surveys

General 9-1

Purpose 9-1

Survey Methods 9-1

Management of Engineering Control Surveys 9-2
- Assignment of Personnel 9-2
- Planning 9-2
- Bridge Surveys 9-3
- Checking 9-3

Safety 9-3

Staking Authorization 9-4

Construction Survey Duties 9-4

Care of Surveying Equipment 9-5

Checking Plans 9-5

Cooperation with Contractor 9-6

Horizontal Control 9-6

Traverse Control 9-7

Establishing Centerline 9-7
- Establishing Additional Control Monuments 9-7
- Random Control Use 9-8
- Centerline Control 9-8
- Setting Centerline Control 9-8
- On-Line Traverse Method 9-9
- Control Method 9-9
- Centerline Reference Points (RPs) 9-9
- Staking Centerline 9-10

Vertical Control 9-10

When Established 9-10

Bench Mark Spacing 9-11
- Permanent Bench Marks 9-11
- Temporary Bench Marks 9-12
- Marking Bench Marks 9-12
- Leveling Accuracies 9-12
- Vertical Control 9-12
- Survey Monuments 9-12
- Relocation of Bench Marks 9-13

Staking Right of Way 9-13

Clearing and Grubbing Stakes 9-13

Cross Sectioning and Slope Staking 9-14
Computer Output 9-14
Planning 9-16
Cross-Section Intervals 9-16
Terrain Considerations 9-18
Tolerances 9-20
Unusual Situations 9-20
Slope Staking with Total Station 9-20
Marking Slope Stakes 9-28
Fill Stakes 9-28
Cut Slope Stakes 9-28
Reconstruction 9-28
Road Approaches, Dikes, Etc. 9-28
Staking Borrow Pits 9-36
Finish Grade Stakes 9-36
Bridge Construction Surveys 9-39
Responsibilities 9-39
Department Responsibilities 9-39
Contractor Responsibilities 9-40
Checking and Inspection 9-40
Preliminary Procedure 9-40
State Plane Coordinates 9-41
Horizontal Control — General 9-41
Horizontal Control — Tangent Dry Land Structure 9-42
Horizontal Control — Dry Land Structure on Curve 9-44
Vertical Control — Construction Grades 9-44
Fill Settlement Check Elevations 9-45
Structure Settlement Check Elevations 9-45
Structures Involving Railroads 9-46
Construction Surveys for Small Drainage Facilities 9-46
General 9-46
Pipe Culverts 9-46
Concrete Box Culverts 9-47
Dikes and Ditch Blocks 9-47
Drop Inlets 9-47
Curb, Gutter and Sidewalks 9-48

Construction Surveys for Miscellaneous Items 9-48
Fence 9-48
Bin Walls and Retaining Walls 9-48
Traffic Control Devices 9-48
Utilities 9-49
Guardrail 9-49
Right-of-Way Monuments 9-49
Right-of-Way Reference Monuments 9-50
Right-of-Way Reference Post 9-50
Monuments Located During Construction 9-50
Comfort Stations 9-50

Figures

9-1 Earthwork Request Form 9-15
9-2 Design and Earthwork Computation Process 9-17
9-3 00 Sections 9-19
9-4 Miscellaneous Cross-Section Problems 9-21
9-5 Roadway Channel Change Cross Sections 9-22
9-6 Overhang Cross Sections 9-23
9-7 Cross Sections for Remeasuring 9-24
9-8 Backslope Rounding 9-26
9-9 Grade Change 9-27
9-10 Slope Stake for Normal fill sections 9-29
9-11 Slope Stake for Fill Section with Safety Shoulder 9-30
9-12 Slope Stake for Normal Cut Section — Example 1 9-31
9-13 Slope Stake for Normal Cut Section — Example 2 9-32
9-14 Slope Stake for Normal Cut Section — Example 3 9-33
9-15 Slope Stake for Cut Section with Flat Bottom Ditch 9-34
9-16 Slope Stake for Daylight Section 9-35
9-17 Borrow Pit Cross Sections — Example 1 9-37
9-18 Borrow Pit Cross Sections — Example 2 9-38

Chapter Nine
Construction Surveys

General

This chapter of the Survey Manual suggests and explains procedures and techniques that promote correct, thorough, and uniform construction staking and measuring.

Purpose

The purpose of construction surveys is to lay out and set controlling points for construction of the project. This includes items such as taking basic measurements that are necessary for determining quantities, and then documenting these various measurements to substantiate the final payment made to the contractor. Construction staking establishes basic line and grade controls, delineates working areas, and serves as a base to verify the locations and quantities of completed work. Normally, the Department provides the essential controls for establishing lines and grades, and the contractor's forces set supplemental stakes for their convenience, particular method of operation, or specific equipment. In some cases, such as for large structures, the contractor may set most of the control points.

Survey Methods

The increased use of computers and specialized design equipment has led to many advances in the entire highway development process. The changed emphasis on computer use and special graphic systems in the location and design process mandates that the preliminary survey be based on a three-dimensional coordinate system.

The benefit of this system is that preliminary survey data and monumentation can be planned for and used to advantage in the construction surveying process. If all control points of the construction plans are tied to a coordinate system, the position of any point, or any references to it, can be calculated. Calculations can be made with hand-held calculators or with personal computers.

One primary example is the method of staking from control points by angle, distance, and elevation difference. This method is called "radial staking" and can meet required accuracy if the distance from the occupied control point to the point being staked is kept within specified limits for the type of instrument used. The computations for radial staking include back azimuth to visible control point(s), azimuth, distance, and difference in elevation (if required) to all points to be set within the specified range from the occupied control point.

The traditional line-reference method for establishing construction control stakes may be used in conjunction with radial methods. A case in point is the setting of intermediate control points on centerline or reference line by radial survey, and the use of traditional line, distance and deflections for intermediate station points.

Management of Engineering Control Surveys

Good management practices are equal in importance to good engineering practices in reducing costly engineering control errors in highway and bridge construction.

The construction survey accounts for a large proportion — nearly 30 percent — of the construction engineering costs. Therefore, special attention is needed to promote efficiency and economy. The district construction engineer is responsible for scheduling surveys, providing the manpower to staff the construction survey teams and ensuring that efficient practice is maintained at all times. However, the field project manager is directly responsible for the construction survey work and must have full knowledge of the proper methods to be used to ensure that the survey is performed properly.

Assignment of Personnel

It is desirable to assign the same personnel to staking the project who performed the preliminary survey. It is generally accepted that more interest is shown and more care taken in survey work when the crew members know that they will be responsible for construction of the facility for which the survey is being made. Personnel — either temporary or permanent — new to highway and bridge staking should be carefully trained and observed. Any person who cannot or will not work to the accuracy required cannot be tolerated because of the high costs of correcting errors.

Planning

Whatever method of staking is used, planning and the effective use of personnel and facilities are essential in providing the most economical survey. Much of the planning, such as layout of horizontal and vertical control, should take place during the preliminary survey. Do not hesitate to set additional control during the preliminary survey for the construction staking phase. Establishment of additional control points must conform with the control traverse requirements. If it is apparent that any traverse control monument will be destroyed during construction, set a new point or reference the existing point.

Generally a lot of time passes, and often radical crew changes occur, between the establishment of the original control and the use of that control for construction staking. The party chief should thoroughly review such items as design plans, horizontal and vertical control listings, and all other design output that could aid in planning the survey. A field review and re-flagging of control points should also be conducted.

Preparing staking notes in the office whenever possible saves costly field crew time and often prevents field-calculation blunders. Before preparing staking notes, review all computer listings thoroughly and verify that the output is based on the same design as shown in the construction plans. Void old information not applicable to the construction plans.

It is imperative to allow sufficient time for checking plans, staking, referencing, and checking of primary controls prior to the beginning of construction. Consideration must be given to expected weather conditions, availability of points, terrain, and the required accuracy of the survey.

Review and check plans prior to beginning staking. Do not grab plans, head for the project and begin staking as soon as you start a project just to keep everyone busy. This can, and very often does, lead to costly errors and aggravating duplication of work. All personnel should at least have an opportunity to review the plans and become familiar with construction details affecting the layout.

Plan layout and referencing to keep duplication of work to a minimum. The time spent on planning, prior to layout, will save valuable time during construction. For instance, it is not reasonable to layout footing centerlines in areas where channel excavation must be removed prior to bridge work.

Bridge Surveys

Layout and engineering control of bridges requires precision not necessary nor generally practiced on most other highway construction. This is due mainly to the materials used in the construction of bridges. Once concrete is in the forms and hardened, correction of any mistakes is very costly and time consuming. Errors in span lengths, column lengths, cap elevations, etc. generally require costly corrections. Very probably, federal participation in these corrections will be limited or nonexistent. For these reasons, it is necessary that every effort be made to provide this precision.

On projects with multiple structures, it is desirable to allow sufficient time for establishing primary controls for all structures because this permits establishing the controls with a minimum of time and effort and frees personnel for inspection duties during construction. The practice of delaying establishment of controls to the last minute or of the project personnel arriving on the project at the time the contractor is ready to begin work leads to a choice between two unacceptable alternatives:

- Suspend the contractor's operations until staking, checking and referencing are complete. The Federal Highway Administration does not recognize this as a legitimate reason for suspension of work and will assess the State liquidated damages if the contract time overruns.
- Provide only minimal staking without proper referencing and staking to allow work to begin. Too often this alternative results in very costly errors. Proper management and planning can eliminate the need to make this choice.

Equipment capable of producing the required accuracy must be made available and used. The precision required for bridge construction survey controls justifies the use of more sophisticated equipment than is normally used on highway work. A theodolite or total station will be made available for primary control system staking for a structure.

Checking

Impress on project personnel the need for constant checking of the work. Make every effort to keep them aware of this need throughout construction. Rough checks that take very little time or effort — visual comparison of column heights to approach fills and other bents, and taping between like units on separate bents — can disclose gross errors in design or layout and prevent costly extra work. The elimination of errors is mainly dependent on constant checking.

Safety

Construction projects can be hazardous working areas because of the concentration of heavy equipment, dusty conditions and, in some cases, normal highway traffic. All employees are responsible for their own safety but should cooperate with other crew members so that safe practices will be in effect at all times. The field project manager is responsible for safe procedures and should ensure that orange vests or jackets, warning signs and hats are properly and appropriately used. New crew members should be carefully instructed in the proper use of hand tools, axes, machetes, brush hooks, traffic control and the like to prevent accidents. Refer to Chapter Three for traffic control signing.

Total stations, theodolites and levels must frequently be set up in the main stream of rapidly moving traffic. In such cases, every reasonable precaution should be taken to provide adequate advance warning to the traffic. Use flaggers when necessary. The Department of Transportation is concerned about possible damage to surveying equipment by traffic, but it is more concerned with the safety of its personnel who must work on the highways.

Any advance warning signs set by survey personnel should be turned away from traffic when they are not needed — during lunch breaks, for example — and should be removed at the end of each

day when their intended purpose has been served. Motorists begin to ignore signs when they do not mean what they say. Courtesy in dealing with the motoring public will help promote a safer construction surveying atmosphere.

Staking Authorization

Construction staking is normally authorized when the project is advertised for bids — two to three weeks before the bids are opened. Frequently, the district construction engineer may wish to begin staking complex projects prior to the advertising date.

Authorization to begin construction surveying prior to contract award can be obtained from the Construction Bureau. On such occasions, the district construction engineer should draft a request stating the reasons for early staking and submit the request to the Construction Bureau. If staking is approved, the Bureau will obtain the proper charge numbers and send them to the district construction engineer with the authorization.

Construction Survey Duties

The field project manager is responsible for establishing lines and grades for all vertical and horizontal controls, normally with assigned employees. However, the specifications may provide for the use of contractor personnel. (Contractor personnel are used primarily on bridges or structures.) Where contractor personnel are used, the full responsibility for the accuracy of lines, slopes, grades or other engineering work remains with the State, and is under the direction of the field project manager and must be thoroughly checked.

Construction survey crews are responsible for many different functions. Some of the more important of these are:

- reproducing and referencing centerline;
- checking, setting or reestablishing bench levels;
- checking plans, grades and calculations;
- performing grade revisions, when necessary;
- measuring and recording clearing and grubbing;
- staking culverts and checking culvert lengths;
- laying out and staking structures;
- taking cross sections and setting slope stakes;
- laying out interchanges, ramps and frontage roads;
- setting finished grade stakes for subgrade, base surfacing and finished surfacing;
- preserving, perpetuating and witnessing survey monuments;
- recording all pertinent survey information in a neat, legible manner in accordance with the requirements presented in Chapter Eleven; and
- providing practical and accurate survey controls in an economical manner. It is important, almost necessary, that the majority of a survey crew be skilled and precise in their duties, but it is also necessary to exchange this information, to communicate knowledge of survey skills to other less informed members of the crew to promote and maintain the degree of morale necessary for efficient surveying. It is very important that the various crew members exchange their knowledge, help each other, and learn the more important details that control the work. This

interchange of knowledge and skills provides opportunity for advancement and provides the field project manager with a team in which any one of the members can substitute for a member who is not present on any particular day.

The field project manager has a duty to see that assigned crew members each have a chance to show their ability in performing such duties as chaining, rodding, running the gun, keeping notes and assisting in planning the survey efforts. When each team member knows the duties of other members, that member is in a better position to cooperate and can better appreciate the overall needs of the work.

Staking crews are generally composed of three members, but the crew size should be flexible to ensure that other phases of the work can be adequately staffed as the need arises. Crews that are adequately staffed or even slightly understaffed are generally more efficient and experience a higher degree of morale than those that are overstaffed.

Field project managers and others who are responsible for construction surveying, whether for entire projects or selected types of surveys, should acquire the tables, handbooks, textbooks or other data necessary for competent discharge of their duties.

Care of Surveying Equipment

The field project manager is responsible for the care of all assigned equipment. Refer to Chapter Three when instructing personnel in the care and handling of surveying equipment. Any individual using survey equipment, especially instruments, must make every effort to prevent their being damaged.

Instruments occasionally are damaged either accidentally or through negligence. Obtain authorization before sending the damaged instruments to the Construction Bureau for repair. Explain the type of damage, the repair needs, and a description of any negligence involved. If damage was caused by the contractor's employees or equipment, the report should reflect this information and the contractor should be advised so the matter may be referred to the contractor's insurance company. Repair and replacement costs are often recoverable from contractors or motorists who have struck instruments. The letter of transmittal accompanying damaged instruments should have a detailed explanation so others can understand how the incident occurred to expedite recovery of repair costs.

The Construction Bureau will make every effort to recover the cost to repair or replace any damaged instrument from contractors or motorists, whether the damage is due to negligence or accident.

Checking Plans

A preliminary review of the plans for the project should be made in the field before any staking is started. A very careful check should be made to assure that drainage facilities are located properly and that drain pipes are of sufficient size to transmit the expected runoff. The location of all farm approaches and business or residence entrances should be checked. Notations can be made for any additional requirements needed to serve new properties that have not been shown on the plans but which may have been in existence at the time right of way was secured. No additions, deletions or revisions should be made to any entrances or condemned property or to controlled access right of way without the approval of the district and the Construction Bureau.

Cooperation with Contractor

Staking is a very critical operation on projects where contractors employ modern, high-production equipment and methods. Detailed planning and intimate cooperation with the contractor are required so staking can begin as soon as is reasonably possible, and as far in advance of construction

as weather and soil conditions will permit. Adequate lead time is essential to prevent delaying the contractor's operation. Staking delays that hinder the construction operations will not be tolerated — assuming reasonable notice of the contractor's plans and intentions have been given to the field project manager.

The field project manager should consult the contractor as soon as possible after the project is awarded to coordinate the staking plans with the contractor's schedule. These discussions may be held before the preconstruction conference, and, if so, the plans should be reaffirmed at the preconstruction conference. It is desirable that the contractor furnish a proposed schedule of operations and keep it updated to allow determination of manpower and equipment needs for timely staking.

The method of staking, how the stakes are to be marked and guarded, what offsets will be used, etc., should be explained. The information placed on stakes, abbreviations, and locations of messages, if not carefully explained to contractor personnel, may result in misunderstanding or misinterpretations and delays.

The need to retain referenced control points and the possible cost to the contractor in terms of stake replacement and work delay awaiting new stakes should be discussed with the contractor. The specifications provide that the contractor be held responsible for preservation of all stakes and marks. If any of the construction stakes or marks are carelessly or willfully destroyed by the contractor, the cost of replacing them will be charged against the contractor and will be deducted from payments for the work. Therefore, if it is necessary to replace stakes removed by the contractor's operation, separate notes should be set up stating the date replacement began, personnel assigned, and the reason for replacing the stakes, so the cost may be properly documented.

If there is any doubt of full understanding of the staking method, stake markings, staking schedules, protection of control points or the State's intention to keep restaking to a minimum, write a letter of explanation to the contractor. This written record may become a valuable aid in the event that portions of the work are not built to the established lines and grades.

The contractor should give notice of the need for stakes, checking of forms, etc. sufficiently in advance to permit timely staking and checking and efficient utilization of project personnel. Procedures for this should be established at the beginning of construction.

Horizontal Control

The construction phase of most projects requires a relatively dense network of horizontal control monuments. This network normally consists of the control monuments that were established during the preliminary survey and control monuments established specifically for construction control. Project control may consist of centerline references or random control monuments from which centerline or centerline references may be set. It is essential that the control used to design the highway be used to construct the highway.

Traverse Control

The control traverse monumentation is the preferred control system for several reasons:

- points can be set where they are not disturbed by construction activities;
- monuments can be used for both horizontal and vertical control, making full use of total station capabilities;
- monuments can be set at optimum spacing for the staking accuracies required and the type of equipment used;

- the same monument is used for setting all phases of construction, including restoration of stakes obliterated during construction operations;
- distance, direction, and elevation calculations can be pre-figured from any control point to any desired construction stake, or such calculations can be made by simple inversing, using hand-held calculators; and
- smaller crews may be utilized, as all measurements are made by the EDM.

Establishing Centerline

The centerline, or another line designated on the plans as the baseline, from which measurements are to be taken for laying out the work and setting stakes for horizontal and vertical control is one of the first procedures in staking a highway project. It is obvious that any stakes set on the centerline will be destroyed during construction operations. Centerline need only be temporarily marked for use during staking. During the course of construction the centerline or baseline will have to be reestablished frequently depending on the nature of the construction.

The plans should be checked and notebooks prepared before any staking is begun and at least one set of plans is to be available for use by the staking party at all times. Occasionally, errors in the plans or the original field location are found by the staking party. Notations of these errors are to be made on the field plans as well as in the notebooks.

Establishing Additional Control Monuments

If additional control monuments are required during construction, they must be surveyed in strict conformance with the methods and procedures described in Chapters Four and Five. With proper planning, much of the necessary control will be included in the original control traverses completed for preliminary survey operations.

A thorough review of construction plans and analysis of staking requirements generally indicates where additional control is required. Interchanges, structures, or other complex facilities usually require monuments in unforeseen locations. Some basic suggestions for establishing additional control monuments are:

- Set monuments by closed traverse between the existing control available.
- Set points where they can be used for setting all phases of construction staking.
- Set points where they are accessible by vehicle, if possible. A vehicle can often be used to shield the instrument person from wind. Also, hand-carrying equipment to an inaccessible point is time-consuming.
- Try to pick locations where the instrument is above all stages of the work. This is particularly advantageous on structures.
- Flag and set witness points next to the new control points so that they are easy to find and will not be disturbed by construction.
- Space control points on both sides of the road to ensure that any required staking point will be within 1,000 feet of a control point.
- The additional control points must not duplicate a number used in the original control traverse.

After construction is complete, enough control must be left on the project so that the elements of a control traverse exist.

Random Control Use

Two basic staking methods are used from control points: direct or traverse. The direct method is the more common and advantageous of the two because it eliminates intermediate steps.

- Direct staking from control points is called radial staking. The system involves the use of inverse calculations that give azimuth and distance, and, where required, elevation from the control monument to the construction stake. If several stakes are set from one control point, the backsight setting should be re-checked during the setup and at the end of the setup to ensure instrument orientation was not disturbed.
- Traverse staking is accomplished by running a line through the points to be staked, and setting the points as the line is run. Control points on the traverse line are established from the control traverse by radial staking. It is often advantageous to set PCs, PTs, TSs, SCs, CSs, STs and, if required, PIs from the control points and then traverse the centerline, or offset line, to set station marks.
- Secondary control such as right of way, centerline references, and pipe or structure reference points may be set from control points.

Centerline Control

Centerline control uses the centerline (or a similar construction layout line) as the principal control line for a project. Because centerline stakes are usually destroyed by construction, strategic points must be referenced outside the construction limits. The reference points provide the horizontal control during the construction period. Some advantages of the centerline method are:

- It is straightforward.
- It is well known by construction people.
- It provides actual on-the-ground checks of centerline. It also provides easy on-the-ground checks for critical clearance points.
- It requires fewer computations.

Some disadvantages of the centerline method are:

- It requires intermediate steps, such as establishing centerline, and centerline references are needed before construction control stakes can be established.
- The principal control line (centerline) is usually destroyed by construction.
- It adapts poorly to steep terrain.
- It often requires more work lines and stakes, making more brushing necessary.
- A larger crew size is needed.

Setting Centerline Control

If a control traverse is used for development of the project, set all critical alignment points directly from the control traverse monuments. In any event, set the alignment control points only from control monuments.

Once the alignment control is set, you have several options for setting the intermediate station points. Select an option based on the personnel and equipment available, terrain, length of time needed, and safety.

On-Line Traverse Method

The traditional system of instrument setups at control points, sighting on line, or turning appropriate angles to set station points may offer some advantages:

- It provides on-the-ground and visual checks of the centerline.
- A transit or theodolite and chain can be used, thus freeing more sophisticated equipment for other work.
- Control references can be set directly at each setup, thus providing a check for any required intermediate references.
- It requires fewer computations. Generally, angles required for curves and adjusted chord lengths can be calculated in the field.

But when the new alignment follows existing alignment, the system may present some overriding disadvantages:

- Instrument setups on pavement often require special treatment, such as traffic control.
- Costs and personnel required for crew protection can become prohibitive.
- Station adjustment is required at each control station, depending on the method and accuracy of measurements.

Control Method

You can set the entire centerline and reference point system from strategically placed, extendable control monuments. This method has some distinct advantages and disadvantages. The advantages include:

- Any section of the project can be set at any time.
- Once the procedures are developed, the method is generally faster and can be done with as few as two people. Three crew members are generally more efficient, as one rodperson can move ahead while the new angle is being turned and the other rodperson is painting or completing installation of the station.
- The method generally provides the best setup and sighting conditions.
- Points can be accurately reestablished to their original position at any stage of the construction.
- Coordinate calculations for curves, spirals and spiral offsets, for instance, can be pre-figured in the office and tabulated for simple reference in the field.

Some disadvantages are:

- Calculations are required for every point, although most calculations can easily be done on hand-held calculators or prefigured in the office.
- The random control net must be of sufficient density that radial points are set no farther than 1,000 feet from the farthest work point. This is particularly critical if a 20-second total station is used.

Centerline Reference Points (RPs)

The cost and time required for resetting stakes, or for setting new lines of construction control stakes, can be reduced by setting easy-to-use reference markers before construction is started. Set the

reference points so they will not be destroyed and so they can be used without special survey equipment to accurately reset the required control stake.

Location. Centerline reference points can be set three feet inside the right-of-way line only if the right-of-way limits are known. Existing fences cannot be considered the right-of-way line. If right of way is unknown, the centerline reference points must be marked to avoid confusion with reference points for the right of way. They can often serve a dual purpose as references for both centerline and right of way.

Type of Reference Points. Use 5/8-inch x 30-inch rebar with a red plastic cap for reference points. Drive the pins to ground level. Set stakes approximately 6 to 8 inches from the RP. RPs set on both sides of the alignment provide both sight and distance reference.

Staking Centerline

Where centerline stakes are needed, centerline control points are set from the reference points or from traverse control points. Centerline is set between the control points, usually on even 100-foot stations on tangents and every 50 feet on curves.

Errors in chaining may occur or be discovered as the centerline is being run and staked. Small chaining errors should be proportioned. Errors resulting in an equation greater than one foot should be recorded. When very large errors in chaining occur, an equation should be made, as near the point of error as possible.

An equation is a survey point that is used to adjust errors in the measured distances and has two station numbers. One of the station numbers is used as a reference stationing for all measurements from the point back toward the beginning of the project. The other is used as a reference station for all measurements from that point ahead. An example of an equation is Station 201+50.0 (back) equals Station 201+28.3 (ahead). This equation is called a plus equation because the length of the line has been increased and in this instance the increase is 21.7 feet. Equations should not occur when a control traverse was used during preconstruction.

Vertical Control

Uniform vertical control is an important part of all engineering projects. A relatively dense network of vertical control — bench marks — must be established for most projects prior to construction staking operations. The network is seldom accomplished in one survey; it usually is a culmination of several vertical surveys beginning with the bench levels. The most important aspect of the various stages of vertical control is that the same datum is used from preliminary surveys through design and final construction control.

When Established

Ideally, most of the project control bench marks are established during the preliminary stage of project development. This existing network is then densified by differential levels throughout the preliminary and construction period. Before the beginning of construction, several steps should be taken.

- If there has been a long delay between the time that the preliminary survey was conducted and the design plans were published, field check the condition of the monuments. Check each monument for possible disturbance or settlement. If a monument is in satisfactory condition, re-flag it for ease in location. Check levels between the adjacent bench marks are required.

- Review design plans thoroughly, and mark up a set of plans with the approximate location of existing bench marks and locations where construction control BMs are required. This can save considerable field time and assure that required bench marks are established at their optimum location on a timely basis.
- During the planning process above, determine the bench lines to be established for the initial grade staking (normally earthwork on main lines and service roads), final grade staking, structure staking, and vertical control monumentation. Plan each bench line to reduce the difficulty and length of level runs required to establish the subsequent bench marks.

Check levels should be run on existing bench marks. If errors are found, corrections should be made and new descriptions for the bench marks established and recorded in the level book with the proper cross references to the original level data. Bench marks that will be disturbed during construction must be replaced outside construction limits and the proper records made.

Bench Mark Spacing

The required density of bench marks depends on terrain, vegetation, and type of construction. There should be enough bench marks to decrease the survey time for subsequent leveling requirements. The advantage of density against the greater initial cost for establishing extra bench marks must be considered.

Place bench marks in locations suitable for the purpose and for permanence.

Bench levels should always be established outside the construction limits. Bench marks that were established during the preliminary survey and are in the way of construction should be reset outside the construction limits. Bench marks should be set no more than 1,000 feet apart using 5/8-inch x 30-inch rebar. Concrete monuments, bridge abutments, or some similar point may be used. The height of fill and depth of cut should be taken into consideration when establishing bench marks so locations are convenient for future surveys performed before, during and after construction of the roadbed.

Permanent Bench Marks

Bench marks that are to remain as reliable elevation references over a period of years, or even for extended construction periods such as for major structures, should generally meet the following criteria:

- They should be placed in stable, undisturbed original ground.
- New bench marks must be established using the requirements and tolerances given in Chapters Four and Five.
- They can be placed on abutments or wingwalls of older existing structures that are stabilized.
- Errors in loops are distributed.
- They should be placed at points of general elevation with the adjacent terrain. A BM on top of a high bluff is not as desirable as one below the bluff, provided all other criteria can be met. Quite often the positions of traverse points are not compatible with project use, and BMs should be established in more usable locations from the traverse control.
- All bench marks should be described in detail as to location and type of bench mark.

Temporary Bench Marks

Less-permanent bench marks may be required for a limited-use period for a specific survey operation — for example, slope staking. Such stakes are called temporary bench marks (TBMs) and are not perpetuated after construction.

TBMs may be wooden 2-inch by 2-inch hubs of sufficient length to be stable, or painted or chiseled marks on concrete or rock outcrops. Temporary bench mark accuracy should be consistent with the type of construction for which the TBMs will be used.

Marking Bench Marks

The density of bench marks in the project area can lead to confusion and possible error because of misidentification. For this reason all permanent bench marks will be a rebar and a stamped aluminum cap. Do not stamp the elevation on the cap. The BM number and date are stamped. Do not duplicate BM numbers used in the preliminary surveys. Identify each bench mark uniquely by name, number, or location. During periods of use, a flagged or painted lath can help the rodperson locate each bench mark quickly.

Leveling Accuracies

The basic procedures are that the levels be closed between the highest-order bench-line points available and that all bench marks are "turned-through" (no side shots), using conventional leveling instruments. Do not use vertical differentials with EDMs to determine bench level elevations.

Vertical Control

The maximum error in establishing or checking bench marks is outlined in Chapter Four. However, an error of 0.05 foot is allowable in level loops for such work as cross sectioning, setting grade stakes and slope staking. The acceptable reading of the level rod is shown below for each type of work:

- 0.01 foot for setting grade for forms, structures, pavements, curbs, gutters, walls, rails and the like;
- 0.05 foot for setting subgrade stakes (bluetops); and
- 0.1 foot when reading ground elevations for cross sectioning and setting slope stakes.

Survey Monuments

Highway construction frequently will destroy property corners, property controlling corners, USC&GS, USGS or NGS bench marks, or other similar monuments. Steps must be taken to preserve all existing monuments after the work is completed. This work may require preparation of a certified corner recordation form. Monuments should be thoroughly and completely protected during the course of construction operations. Steps should be taken by the field project manager to preserve all found or set monuments on the project. Contact Photogrammetry and Surveying prior to the destruction of any monument.

The plans should be examined for the location of section lines or subdivision lines that cross or intersect other lines within the limits of the right of way. The plans may indicate the location of monuments. Notations should be made in field notebooks of the indicated monuments and land line intersections so the locations may be investigated for existing monuments. Careful notes, including descriptions of the corners found and referenced, should be made. If required, a corner record must be filed with the County Clerk and Recorder as soon as monuments have been set. This filing is

accomplished in conjunction with Photogrammetry and Surveying. Refer to Chapter Six for the procedures and forms.

Relocation of Bench Marks

Frequently new construction or repairs to existing structures necessitates the destruction of NGS bench marks, in spite of the fact that every effort has been made to place them where they will be as permanent as possible. The National Geodetic Survey has no funds to pay field parties to relocate these marks when they must be moved. If these marks are to be preserved for the use of all engineers and surveyors, we must depend on the cooperation of engineers and others for assistance in their preservation. Obviously, it is in the best interests of all concerned that bench marks be relocated rather than destroyed.

The proper procedure is to establish a temporary bench mark in a safe place nearby and transfer the elevation from the old mark to the new one. The levels should be run in duplicate to avoid the possibility of large errors. All readings should be made to three decimal places to preserve the accuracy of the original elevation. An assumed elevation for the old mark may be used in the transfer, since the principal concern is the difference in elevation between the old mark and the new one. Refer to the sample notes in Appendix A.

The old mark should not be disturbed until the temporary bench mark is established and checked.

The cooperation that individuals and organizations may extend to the National Geodetic Survey in preserving bench marks will be a service to all who may have occasion to use these marks in the future.

Staking Right of Way

The right-of-way plans and a transcript of each right-of-way parcel must be used to ensure that right of way, as shown on the plans, is staked as legally described and intended. Should assistance be necessary, Right of Way may be contacted to help interpret the information. The setting of right-of-way monumentation should be accomplished prior to staking the right-of-way lines. Stake right-of-way lines on both sides of the construction centerline. The distance between stakes will vary according to terrain, but intervals of 100 feet are preferred on level ground and 50 feet on curves. Stakes should be set at all corners and at changes in width or direction. Property owners use these stakes to reset fences, determine property lines, etc. Therefore, accuracy is important. Mark the front of the stake with "R/W," station, and the distance from centerline. The back of the stake is blank.

When staking right-of-way lines on curves, the distances must be adjusted in proportion to the difference in the radii between the right-of-way line and the centerline or baseline.

Clearing and Grubbing Stakes

The Standard Specifications provide three methods of measuring clearing and grubbing units: a lump sum basis, area basis and individual unit basis. Staking must be compatible with the method of measurement. Clearing and grubbing limits are always established within the right of way with due allowance for movement of contractor equipment. Sharp breaks in the width of the clearing line may be avoided by adjusting clearing stakes. Clearing lines on the inside of curves and at intersections should be given special attention to provide adequate sight distance when the right-of-way widths will permit.

Distances will be measured to the nearest foot, and stakes or laths will be placed to clearly distinguish the intended limits. Stakes or laths should be spaced approximately 100 feet apart, as a rule, and placed so one lath can be seen from the next one. Spacing will depend on the terrain and denseness of the foliage. When clearing areas of heavy timber, clearing stakes should be set in a somewhat irregular alignment so when clearing is completed a more natural appearance will result. Stakes or lath properly set are marked "clear" and are usually flagged.

The stakeout notes will show stationing, distance left and right, date, and names of persons making the stakeout. The areas that have been staked should be reviewed with the contractor's supervisors so they are aware of the staking procedure and the general areas to be cleared or grubbed, and so they can raise any questions before work begins.

A limited number of trees and shrubs may be retained to blend the right of way with adjacent terrain, providing screens for unsightly areas, and enhancing the natural appearance. Mark the trees to be saved with a red cloth or other suitable identification and inform the contractor that trees so marked are not to be cut. Trees and shrubs to be retained should be sound, vigorous, and of a desirable species that will not create future maintenance problems.

Cross Sectioning and Slope Staking

Design quantities are calculated from field cross sections or from cross sections derived through the photogrammetric process. Normally, the staked location and elevation should agree fairly closely to the plotted location and elevation. A shot that falls within 2 feet in distance and less than 0.5 foot in elevation is acceptable does not require complete re-cross sectioning. If the plotted and staked locations disagree, the staked position, as reflected in the staking notes, is used for final quantities.

Computer Output

The Road Design System (RDS) computer programs are currently being reviewed and some changes may be made in the near future. The following briefly describes existing computer output.

On projects designed under RDS, several forms of staking information are available. Some of the information may be produced by the designer on a routine basis, while other listings must be requested.

Roadway design and earthwork computation are accomplished using the Earthwork Request Form, Figure 9-1. In this process, the engineer can have RDS perform:

- horizontal position calculations,
- right of way and maximum slope intercept updates,
- roadway design,
- volume calculations, and
- haul calculations;

and produce:

- alignment relations listings (horizontal position),
- right of way and maximum slope intercept listings,
- profile grade listings,
- staking detail listings,

Figure 9-1
Earthwork Request Form

ROAD DESIGN SYSTEM
EARTHWORK REQUEST FORM

SHEET.....OF.....
PREPARED BY.....
DATE.....
REGION.....PRK/FOR.....
STATE.....PROJ.....
CO.....HWY.....

IDENTIFICATION
1 12
N,T,P, 3,C,6,R,E,R,W,K

FROM BASELINE STATION	TO BASELINE STATION	HORIZONTAL POSITION CALCULATION							ROW & MAX. SLOPE INTCP. UPDATE	DESIGN (YES OR NO)	VOLUME & HAUL CALCULATIONS											CONSTRUCTION STAKING REPORT							AUXILIARY LISTINGS						
		YES OR NO	ROADWAYS INCLUDED								VOLUMES (YES OR NO)	ROADWAYS INCLUDED IN VOLUME						LIST EVEN STA.	1401 QUANT.	CORR. F/CURVE	HAUL PLOT (P)	HAUL PLOT (D)	FREE HAUL DIST.	YES OR NO	ROADWAYS INCLUDED						HUB NO.	WIDE	LO-HA	STAK.DET.	TOE SLOPE	DES. X	GRADE
			A	B	C	D	E	F				A	B	C	D	E	F								A	B	C	D	E	F						
1 21	22 30	31 33	34	35	36	37	38	39	40 42	43 45	46 48	49	50	51	52	53	54	55	56	57	58	59	60 63	64 66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1,00.00.	3,25.00	YES	X	X																																	
1,0,0.00.	3,26.	NO							YES	YES																									X		
1,00.00.	3,25.	NO							NO	NO	YES	X							X		X		1,000														
1,00.00.	3,25.	NO							NO	NO	YES		X						X				1,000														

- design cross-section listings,
- earthwork quantities listings,
- toe-of-slope printer plots,
- construction staking reports,
- mass diagram and haul plots, and
- widening listings.

The design and earthwork computation process is shown schematically in Figure 9-2.

Slope stake books for fill sections normally show centerline, shoulder and fill catch points. Before staking, review the slope stake output against the design plans to be sure that points are included and properly coded for such items as safety shoulder, extra widening, or superelevation. Such points can be missed by the designer and cause considerable problems for the survey crew. Although its full ability normally is not used, RDS has the ability to list up to 16 roadway grade points for each earthwork station. Such information can be useful for such special purposes as sidewalk, curb and gutter.

Planning

All such preliminary work as centerline staking, establishing bench marks and offset lines and preparing a grade book or a system of grade computation sheets will greatly aid the cross-sectioning and slope-staking crew. When clearing and grubbing is necessary prior to cross sectioning and slope staking, it will be wise to anticipate the most probable location of slope stakes. Cross sectioning will usually be performed when slope staking.

Slope staking and measurement of earthwork quantities are areas where more disputes with contractors arise than any other phase of highway work. Therefore, it behooves the field project manager to do careful planning and sufficient preliminary work in ample time to permit cross-sectioning work to follow in an orderly manner.

Cross-Section Intervals

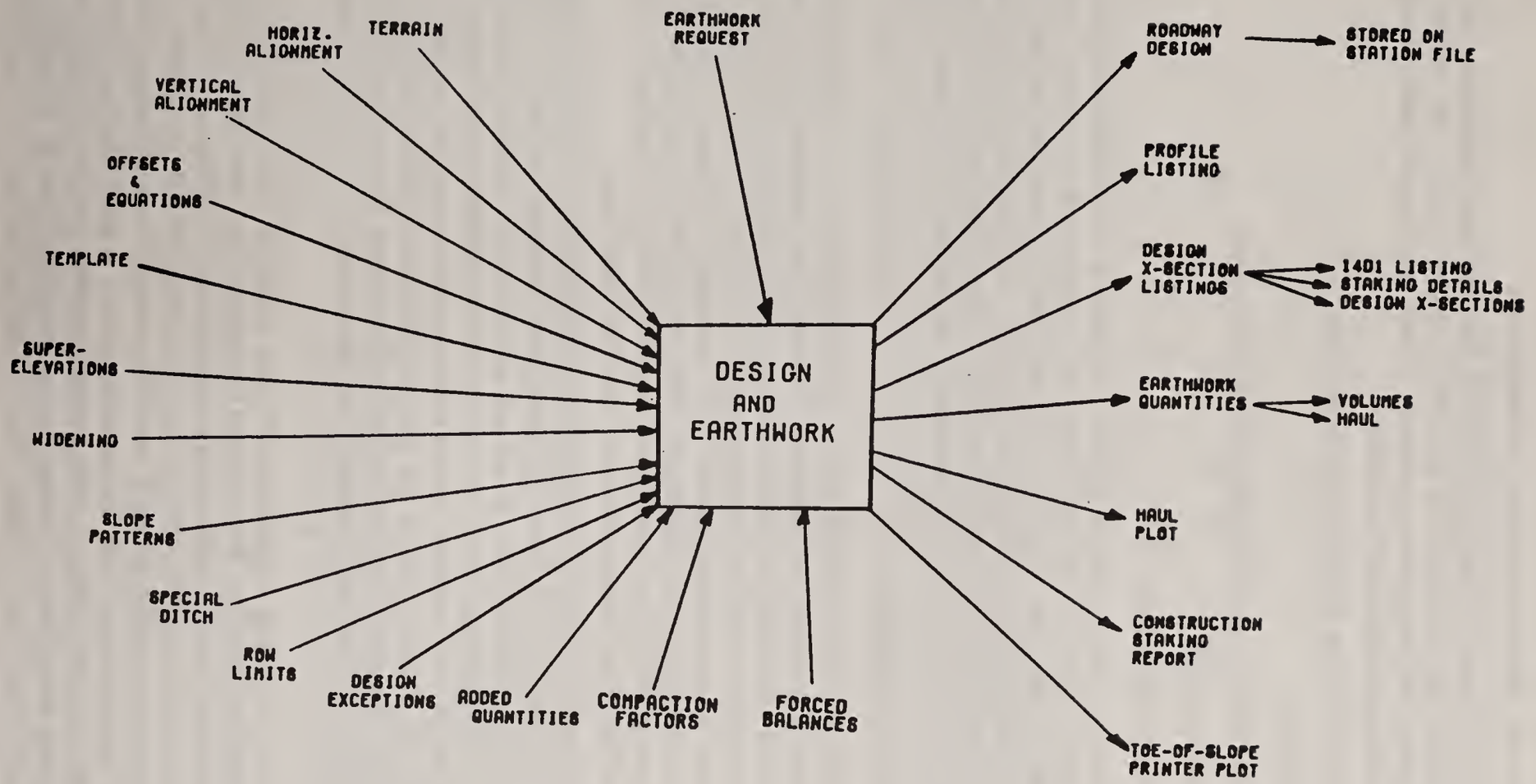
The field project manager must decide when and where to take a cross section. Bear in mind that a recorded cross section is the basic information for determination of contractual pay quantities and that the contractor and field project manager need a certain quantity of stakes, properly located, for construction of the roadway to specified dimensions. Take sufficient cross sections, at proper locations, to truly reflect the quantities of earth to be removed.

The normal cross-section interval will be 100 feet. However, in flat, low terrain longer intervals may be used and in rugged or mountainous terrain 50-foot intervals may be necessary. Other cross sections must be taken at odd intervals where significant changes in elevation are noted. Sections will be taken at all breaks in the centerline profile and at all other breaks in topography within the roadway prism and at cut to fill transitions.

An allowance should also be made for earthwork volumes around curves by decreasing the spacing of cross sections. This procedure will help compensate for inaccuracy of the average end area method (a specification requirement) of computing earthwork quantities around curves. When encountering horizontal curves, the cross-section interval should be:

- curves with less than a 5,000-foot horizontal radius, use 50-foot intervals;
- curves with 300-foot or less radii, 25-foot intervals; and

Figure 9-2
Design and Earthwork Computation Process



- curves with 100-foot or less radii, 10-foot intervals.

Use 50-foot intervals on vertical curves when the midordinate between the curve and chord varies 0.2 foot or more between stations. It is common practice to take a cross section at each 100-foot station; however, that is not always necessary if other sections taken nearby more truly reflect the ground situation. Sections should be taken at:

- PCs and PTs or the beginning and end of spirals,
- all equations,
- the beginning and end of superelevation runoff to curves,
- drainage sites, and
- other pertinent locations.

It is not always necessary to put stakes in the ground at intersections of template and ground. For example, cross sections may be needed every ten or fifteen feet for quantity determination but the contractor needs stakes only every 50 feet. Earthwork computations will compute all template-ground intersections between outside catch points. However, it is absolutely necessary that all groundline breaks and template breaks be recorded and that the outside slope catch points be found and recorded. The party chief doing the staking must not deviate from this basic requirement. See Figure 9-3.

Terrain Considerations

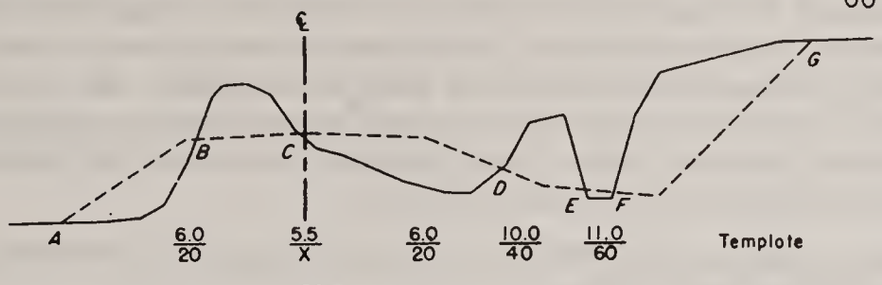
Construction volume computations may change significantly from the plan quantities unless cross sections are taken truly perpendicular to the centerline on tangents and to radius lines on curves. Where the right of way has been staked and lathed, sighting between centerline and the right-of-way stakes can ensure that cross sections are perpendicular. Right-angle prisms may be used to determine the perpendicular line on generally level terrain, but it may be necessary in rough or heavily timbered terrain to use a total station for right angles. In very rugged terrain, it may be necessary to run a series of offset lines parallel to the construction centerline before slope staking and cross sectioning to maintain right angles and to provide another line of elevation points.

As the depth of cut increases and virgin terrain is encountered, it is becoming a common practice in highway backslope design to build compound slopes or slopes with benches or breaks in the back slope. The staking practices now in use will give generally satisfactory results with only minor changes. It is suggested that only sufficient reference to cut depth be given to allow excavation down to the bench break, then reestablish another reference stake at or near the first bench or break to allow excavation down to the next bench, etc. This method of staking ensures that benches or breaks will be constructed correctly and has the advantage of simplicity. However, any other method that will provide proper slopes and place benches of the designed width in the correct location will be satisfactory.

When cross sectioning steep slopes, efficiency and speed can be aided by using reference hubs wherever possible. Elevations that are above the height of the rod or above the height of the instrument can be marked on the reference hub to be picked up on another set of cross sections. A reference line may also be used. The zero end of the tape should be held on centerline in most cases and the cross sections taken right and left of construction centerline and extending to the right-of-way line or beyond the construction limits or construction permit. A prismoidal correction is rarely used but may be required on the inside of circular ramps to correct earthwork computations because of the extremely short radius curves. The main line sections should then be extended or a supplementary baseline used to cover these locations. Notes for staking the grade on ramps or interchange areas

Figure 9-3
00 Sections

"00'S"

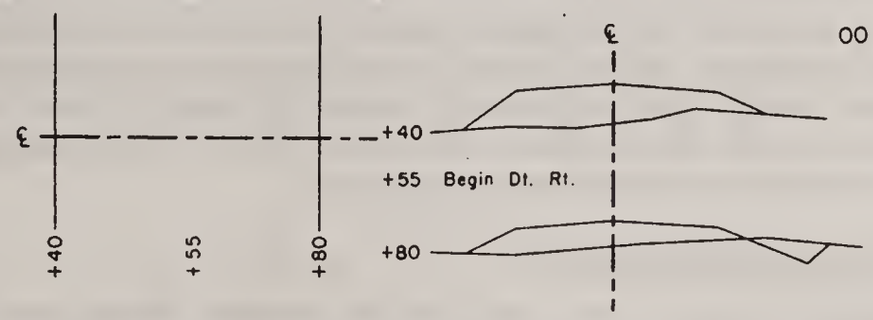


						F0.5								Templote
						6.0								
					6.0	5.5	6.0	10.0	11.0					
					20	X	20	40	60					
8.0	2.6	1.5	1.3	2.2	5.0	6.0	6.8	7.3	9.5	10.5	10.6	8.4	4.6	4.0
20	16	14	10	6	2	X	2	6	16	24	28	32	38	44
			F7.1	F7.3					C13.3	C13.0				
11.4	12.6	13.0	13.1	13.3					+2.3	+2.0	0.5	4.0	11.0	11.0
24	28	36	41.3	50					96	86.0	60	56	52	48
				R					R					

Ground

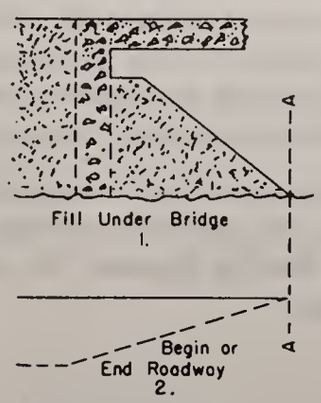
THIS DIAGRAM SHOWS HOW SOME STAKING TIME CAN BE SAVEO IF THE ENGINEER IS AUTHORIZEO TO TAKE SUCH A SHORT-CUT. IT IS AN ACCEPTED CONTENTION THAT ALL GROUNDLINE BREAKS MUST BE PROPERLY CONSIDERED AND RECORDED IF PROPER QUANTITIES ARE TO BE OBTAINEO. THE DIAGRAM SHOWS SEVERAL INTERSECTIONS OF TEMPLATE AND GROUNDLINE. THE RODMAN, UNLESS HIGHLY EXPERIENCEO, COULD SPENO CONSIDERABLE TIME IN FINDING THE INTERSECTIONS AT 'B', 'C', 'D', 'E' AND 'F'. WHEN THERE ARE FREQUENT SECTIONS INVOLVED, THE TOTAL TIME CONSUMED IN A DAY WOULD BE QUITE CONSIDERABLE. THE GROUNOLINE SHOWN, OF COURSE, REFLECTS MORE READINGS THAN MOST FOR A NARROW WIOTH. IF THE ENGINEER WERE TO RECORO ALL OF THE BREAKS NECESSARY IN THE GROUNOLINE, ALL OF THE BREAKS IN TEMPLATE, AND THE TWO INTERSECTION POINTS AT 'A' AND 'G', THE ELECTRONIC COMPUTER WOULD FIND ALL OF THE OTHERS DURING THE PROCESS OF AREA DETERMINATION. IT WOULD BE QUITE LIKELY THAT THE ENGINEER WOULD NOT KNOW OF THE TWO "00'S" AT 'E' AND 'F'. IT IS ABSOLUTELY NECESSARY THAT THE TWO OUTSIDE CATCHS, 'A' & 'G', BE FOUND AND RECORDED IN THE FIELD BECAUSE THESE ARE TEMPLATE DATA AS WELL AS GROUNOLINE DATA. THE COMPUTER WILL MAKE THE ENTIRE AREA DETERMINATION IN ABOUT 15 SECONOS. THE ENGINEER IS CAUTIONED, HOWEVER, THAT IN FOLLOWING THE PRACTICE COVERED ABOVE, HE MUST NOT GET 'SLOPPY' AND MUST PUT IN ENOUGH STAKES ALONG THE ROADWAY TO COVER THE REQUIREMENTS OF GOOD CONSTRUCTION. THIS WOULD BE A VERY ADVANTAGEOUS PROCEDURE WHEN CROSS-SECTIONS ARE CLOSELY SPACED.

00 DITCH



THE ABOVE SKETCHES ILLUSTRATE A TYPICAL SITUATION. THESE SKETCHES INDICATE "BEGIN DITCH RIGHT". THE CONDITION COULD BE "END DITCH RIGHT OR LEFT" OR "BEGIN DITCH LEFT". LET IT BE SUPPOSED, IN THIS CASE, THAT THE DITCH WOULD ACTUALLY BEGIN AT +55 ON THE RIGHT. IT IS NECESSARY TO TAKE A CROSS-SECTION AT +55. AN ENTRY IN THE NOTES "BEGIN DT RT +55" WILL NOT SUFFICE. SEE PLATE VII-05-01.

'00' SECTION



Also applicable to fills.

(B) THERE ARE OCCASIONS WHEN IT IS NECESSARY TO SHOW THE ENO OF A FILL OR END OF A CUT WHERE THE END AREA WILL BE ZERO. TWO EXAMPLES ARE SHOWN AT THE LEFT. THE ROD READINGS IN BOTH CASES CAN BE EITHER ACTUAL OR FICTICIOUS--PROBABLY FICTICIOUS UNDER THE BRIDGE. THE STATIONING SHOULD BE ACTUAL. THE DISTANCE FROM CENTERLINE NEED BE NO CLOSER THAN APPROXIMATE--WITHIN 5 FEET IS CLOSE ENOUGH. THE READINGS ON STATION A ARE SHOWN BELOW.

Case 1.	Templote	5.6/19	4.9/00	4.7/19
	Groundline	5.6/19	4.9/00	4.7/19
Case 2.	Templote	3.2/25	3.2/00	3.2/25
	Groundline	3.2/25	3.2/00	3.2/25

Preceding sections should be token as conditions require.

should be made up ahead of time and should be sufficiently accurate to allow ready staking, but not so precise that weeks will be taken to make thses notes.

All cross sections should extend completely beyond any work that might be done by the contractor in constructing to the requirements of the plans. Groundline readings should extend a reasonable distance beyond the outside grading stake. Extend cross sections beyond construction limits a minimum of 10 feet. In areas where overbreak or slides are anticipated, the cross sections should be extended farther. Construction cross sections should be taken wide enough to include all possible areas that might be disturbed. This will help eliminate backtracking and extending cross sections when later construction activities demand wider areas.

Cross sections cannot exceed 1,000 feet in length from centerline or baseline because of limitations of the existing computer programs.

Figures 9-4 to 9-9 show examples of cross sections for surfacing thickness changes, ditch widening, channel changes, overhang, remeasures, backslope rounding and grade changes.

Tolerances

The instrument height is to be recorded to the nearest 0.01 foot and rod readings taken to the nearest 0.1 foot from a rod held vertically.

Unusual Situations

Infrequently, the field project manager may encounter an unusual problem or situation that does not fit the above procedures. When that happens, and quantities are to be determined by computer, the field project manager should contact the Construction Bureau to reach an agreement as to procedures and methods to follow. Considerable time can be saved by determining the capabilities of the computer programs before the field work is performed.

Slope Staking with Total Station

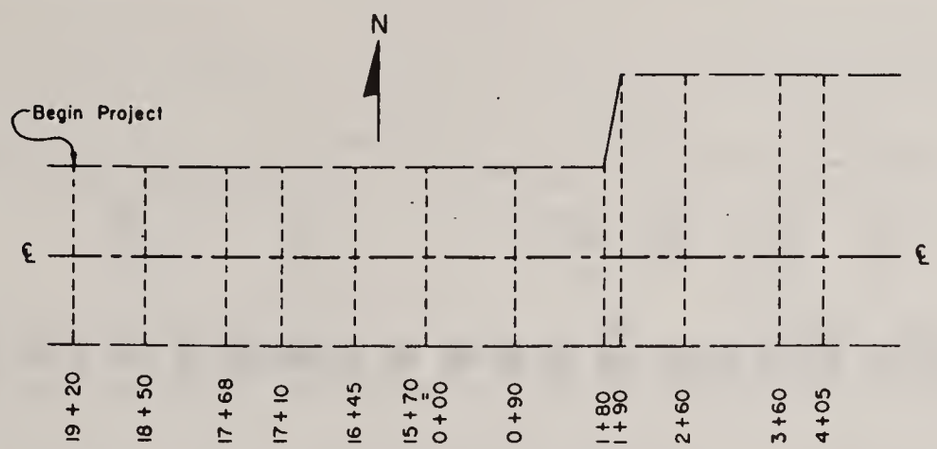
The availability of programmable calculators and coordinate listings makes using total station instruments a valuable option for slope staking, particularly in rough terrain.

The first requirement for radial slope staking is that two control points be available and that the instrument point be within 1,000 feet of the farthest slope stake to be set from that point. In addition, coordinate listings should be available for the control points and slope stake positions and elevations.

To establish the horizontal position of each slope stake, set the instrument over a control point. Backsight another control point with the calculated back azimuth set on the horizontal circle. Turn the calculated back azimuth to the slope stake being set. Direct the rod person on the line of sight to the calculated distance of the slope stake. In the case of fill, set a temporary stake at the point.

The instrument person then sights the new point, without disturbing the instrument orientation to the backsight, and records a new DE. The fill and distance from centerline are computed. If this point does not catch, the procedure is repeated until the catch point is obtained. The instrument person records the azimuth, distance and elevation to the catch point.

Figure 9-4
Miscellaneous Cross-Section Problems



THIS SKETCH IS PREPARED TO REPRESENT SEVERAL SITUATIONS COMMONLY ENCOUNTERED.

1. THE PROJECT BEGINS ON A SURVEY WHICH IS STATIONED FROM EAST TO WEST. THE BEGINNING OF THE STATIONING IS 15+70 WHICH IS EQUAL TO 0+00 ON A SURVEY PROCEEDING FROM WEST TO EAST. CROSS-SECTIONING SHOULD BEGIN AT 19+20 AND RUN EASTWARD THROUGH 18+50, 17+68, 17+10, 16+45, 15+70, 0+00, 0+90, 1+80, ETC., ETC. THEN WHEN THE QUANTITIES ARE WORKED UP THE MASS WILL DEVELOP PROPERLY. THE SAME PROCEDURE WOULD HOLD IF THE STATIONS FROM 19+20 to 15+70 WERE MINUS DISTANCES FROM 0+00, LIKE -3+50, -2+80, -2+08, -1+40, -0+75.

2. THE SURFACING THICKNESS CHANGES 0.8 FT. AT STA. 17+10. THE NOTES WOULD BE RECORDED SOMETHING LIKE THIS:-

H.I. 2334.97

17 + 10
29.00

				6.4/20		6.0/X		6.4/20	9.4/35				
F5.2		F3.9				F1.2		00		C6.0	C2.6		
11.2/50 R	11.2/33	10.3/25.9	9.3/18	7.3/6		7.2/X	6.9/7	6.2/10	3.3/22	3.4/47.0	3.4/50 R		
			7.2/21.2			6.8/X		7.2/21.2	9.4/35				
		F3.1				F0.4	00				C6.0		
11.2/50	11.2/33	10.3/25.9	9.3/18	7.3/6		7.2/X	6.9/5	6.9/7	6.2/10	3.3/22	3.4/47.0	3.4/50	

17 + 10
28.02

NOTE THAT THE SAME STATION NUMBER IS USED FOR BOTH SECTIONS. THE COMPUTER WILL SUBTRACT THE STATION NUMBER, GET A DISTANCE OF ZERO AND THUS THERE WILL BE NO VOLUME.

3. THE DITCH SECTION IS WIDENED ABRUPTLY AT STATION 1+80--1+90. THE NOTES WOULD BE RECORDED SOMETHING LIKE THIS:

H.I. 2630.00

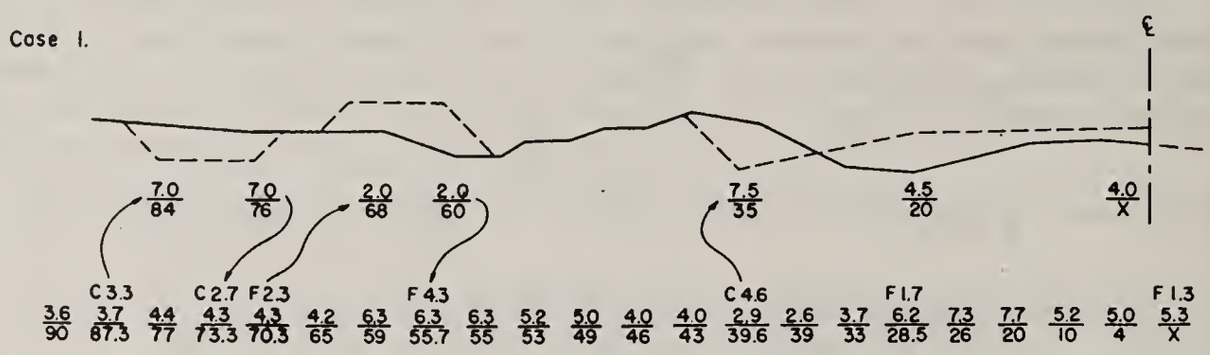
1 + 80
26.00

			8.4/40	4.4/20	4.0/X	4.4/20					
C1.1		C2.8		F1.4	F1.6			F4.2	F4.7		
2.9/100 R	3.6/70	5.6/45.6	6.0/42	5.8/27.0	5.6/X	6.5/14	8.6/24	8.6/26.3	8.7/50 R		

1 + 90
26.00

			8.4/85	4.4/20	4.0/X	4.4/20				
C1.1	C5.5			F1.4	F1.6		F4.2			
2.9/100 R	2.9/96.0	3.6/70	6.0/42	5.8/27.0	5.6/X	6.5/14	8.6/26.3	8.7/50 R		

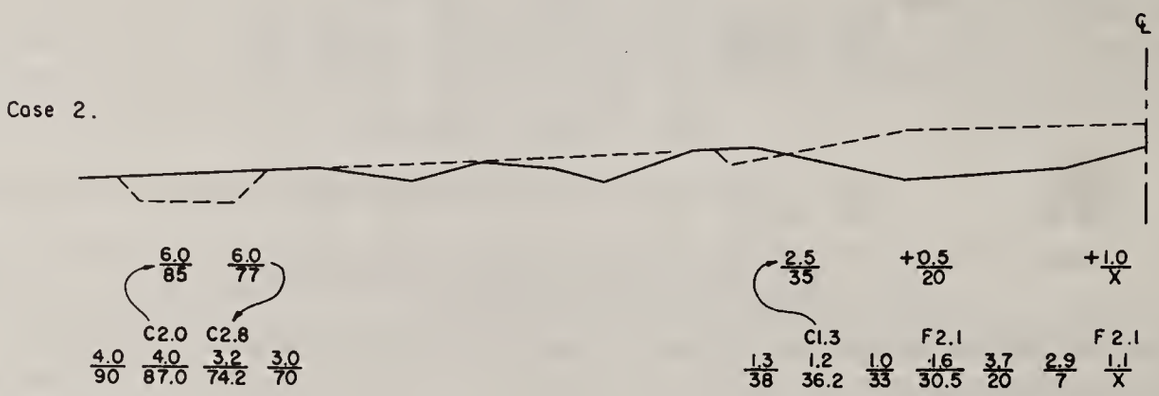
Figure 9-5
Roadway Channel Change Cross Sections



(CASE 1) THIS ILLUSTRATES A CHANNEL CHANGE AND OIKE, WIDELY SEPARATED FROM THE ROADWAY, AND HOW THE NOTES CAN BE RECORDED FOR EASE IN COMPUTER OPERATION. THE TWO SITUATIONS SHOWN ON THIS PLATE ARE THE ONLY ANTICIPATED CASES THAT WILL REQUIRE THE USE OF ARROWS. THE ARROWS CAN BE AVOIDED BY ENTERING IN THE TEMPLATE LINE ALL OF THE INTERSECTIONS OF TEMPLATE AND GROUND FROM 39.6 TO 73.3. IT APPEARS BETTER TO USE THE ARROWS.

THE PUNCH CARD OPERATOR WOULD START THE TEMPLATE READINGS AT 87.3 AND FOLLOW THE ARROWS TO CENTERLINE, AND BEYOND. GROUND WOULD START AT 90 AND BE PUNCHED STRAIGHT THROUGH TO CENTER.

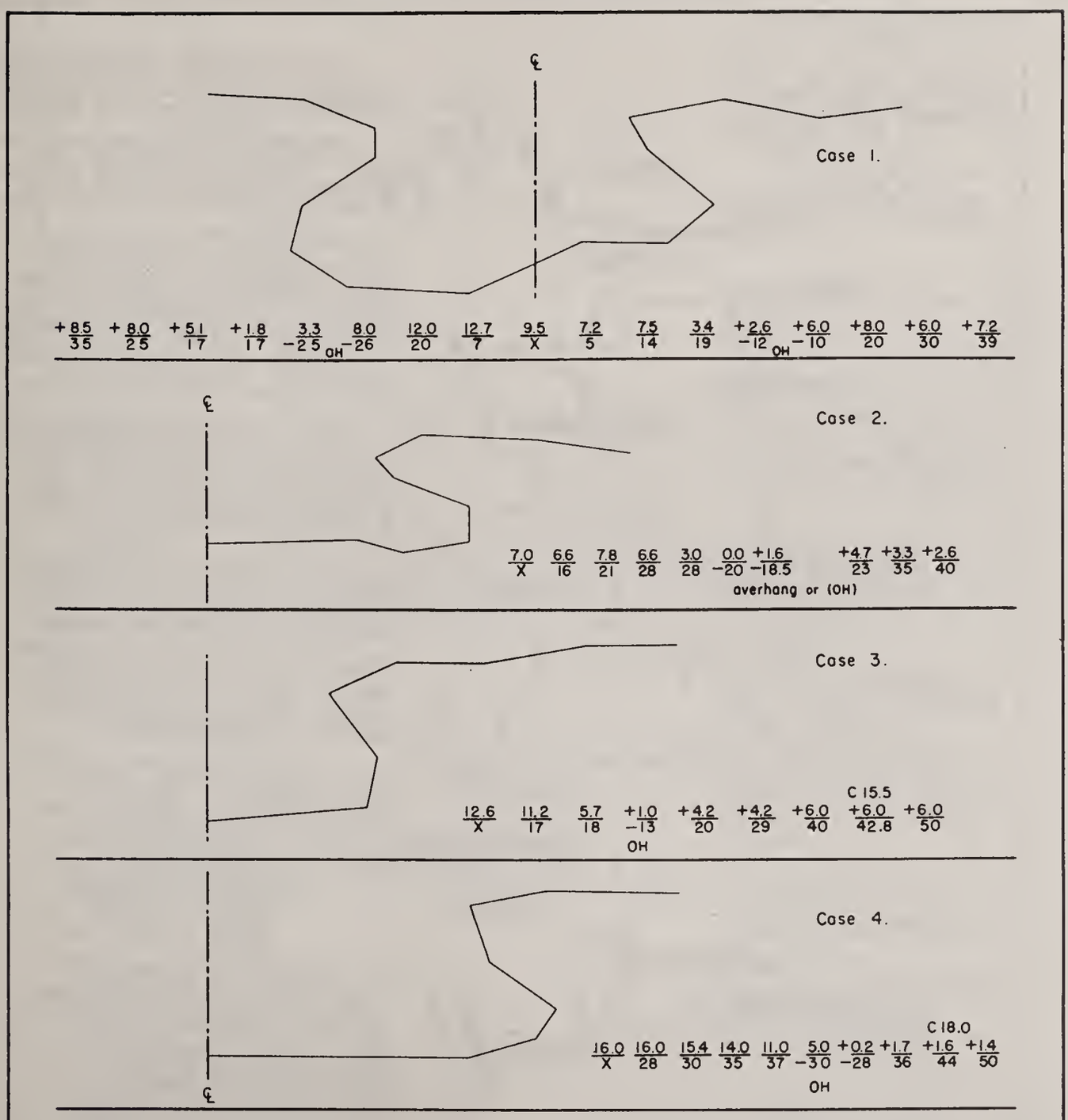
ARROWS MUST POINT FROM LEFT TO RIGHT, REGARDLESS OF WHETHER SECTION IS LEFT OR RIGHT OF CENTERLINE.



(CASE 2) THIS CASE IS SIMILAR TO CASE 1, BUT NO OIKE. IT IS CLEARLY UNDERSTOOD THAT THERE WILL BE NO GRADING DONE BETWEEN 38 AND 70. THE GROUND LINE SHOTS ARE SKIPPED BETWEEN THOSE TWO POINTS. THE TEMPLATE CARD WILL START AT 87.0 AND FOLLOW THE ARROWS TO CENTERLINE, AND BEYOND. THE DASHED LINE BETWEEN 38 AND 70 SHOWS THAT NOTHING WILL BE PUNCHED AS TO TEMPLATE AND GROUND BETWEEN THOSE TWO POINTS. THE SAME PROCEDURES CAN BE APPLIED TO FRONTAGE ROADS.

THERE WILL BE CASES WHERE THE ENGINEER WILL PREFER TO RUN SPECIAL CENTERLINE OR BASE LINE FOR THE CHANNEL CHANGES, ETC.

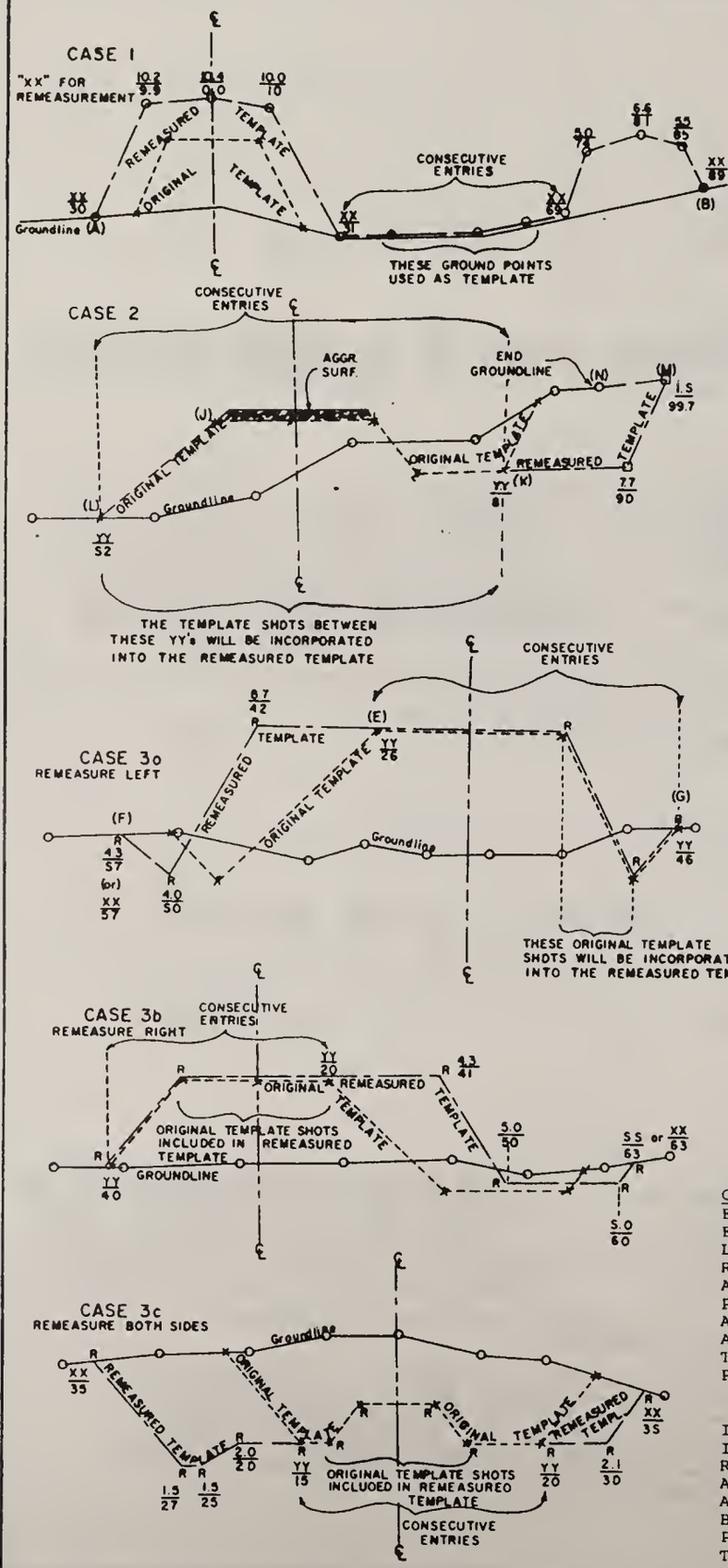
Figure 9-6
Overhang Cross Sections



THIS PLATE ILLUSTRATES HOW NOTES SHOULD BE RECORDED WHEN AN OVERHANG OR CAVE IS ENCOUNTERED.

CASE 1 SHOWS AN OVERHANG ON EACH SIDE OF CENTERLINE. THE NOTES SHOW HOW THE GROUND LINE CAN BE RECORDED SO AS TO DETERMINE QUANTITIES. NOTE THE MINUS DISTANCE READINGS AT 25 AND 26 LEFT OF CENTERLINE AND AT 12 AND 10 RIGHT OF CENTERLINE. ANY HORIZONTAL READING THAT REVERSES, READING FROM THE LEFT, BEARS A MINUS SIGN (-25). THE READINGS AT 25 AND 7 ARE PLUS WITHOUT THE SIGN. WHEN THE RIGHT SIDE IS RECORDED, THE MINUS SIGN OCCURS WHEN THE DISTANCE FROM CENTERLINE DECREASES -- THUS 12 AND 10 SHOULD HAVE A MINUS SIGN. THE MINUS SIGN, IN SUCH CASES, INDICATES A REVERSE DIRECTION IN GROUND LINE AND NOTHING ELSE.

Figure 9-7
Cross Sections for Remeasuring



IT WILL BE NECESSARY THAT PARTS OF SOME PROJECTS, AND SOMETIMES ALL, BE REMEASURED IN ORDER TO DETERMINE CORRECT PAY QUANTITIES. IT ALWAYS OCCURS WHEN BORROW PITS ARE USED.

REMEASUREMENT CAN BE CONDUCTED JUST THE SAME AS ORIGINAL CROSS-SECTIONING, ONLY EASIER. IT IS MORE LIKE LOCATION CROSS-SECTIONING. REMEASURE NOTES MUST NOT BE INSERTED INTO THE ORIGINAL GROUNDLINE NOTES.

THE ENGINEER MAY USE ANY H. I. HE WISHES. IT NEED NOT TIE INTO THE CONSTRUCTION STAKING H. I. IT IS NECESSARY, HOWEVER TO REMEASURE AT THE SAME STATIONS AT WHICH CONSTRUCTION STAKING WAS CROSS-SECTIONED. IF IT IS NECESSARY (E.G., ROCK WORK) TO ADD SOME NEW SECTIONS ON REMEASURE THAT WERE NOT IN THE ORIGINAL STAKING, THE FIELD ENGINEER MUST INTERPOLATE THE GROUNDLINE SECTIONS. INTERPOLATED SECTIONS SHOULD BE SUBMITTED AS SUPPLEMENTARY NOTES.

AN "XX" CODED INTO A TEMPLATE SECTION WILL CAUSE THE COMPUTER TO INTERPOLATE AN ELEVATION FROM THE GROUNDLINE DATA AT A CERTAIN DISTANCE. THE USE OF "XX" RODS HAS NO RESTRICTIONS AS TO NUMBER, PLACE, OR ORDER PER SECTION. "XX" MAY BE USED IN EITHER ORIGINAL TEMPLATE NOTES OR REMEASURE NOTES.

A "YY" ROD MAY BE USED IN REMEASURED TEMPLATE NOTES ONLY. "YY" RODS MUST BE CODED IN PAIRS IN ORDER TO INCORPORATE A SPECIFIED PATTERN OF THE ORIGINAL TEMPLATE INTO THE NEW REMEASURED TEMPLATE.

CASE 1. THIS IS A NORMAL CASE WHERE THE ENGINEER ELECTED TO USE DISTANCES ONLY AND "XX" FOR RODS, AT THE CATCH POINTS, A AND B. THIS IS COMPLETELY IN ORDER INASMUCH AS THE GROUNDLINE EXTENDS BEYOND THE REMEASURED SECTION.

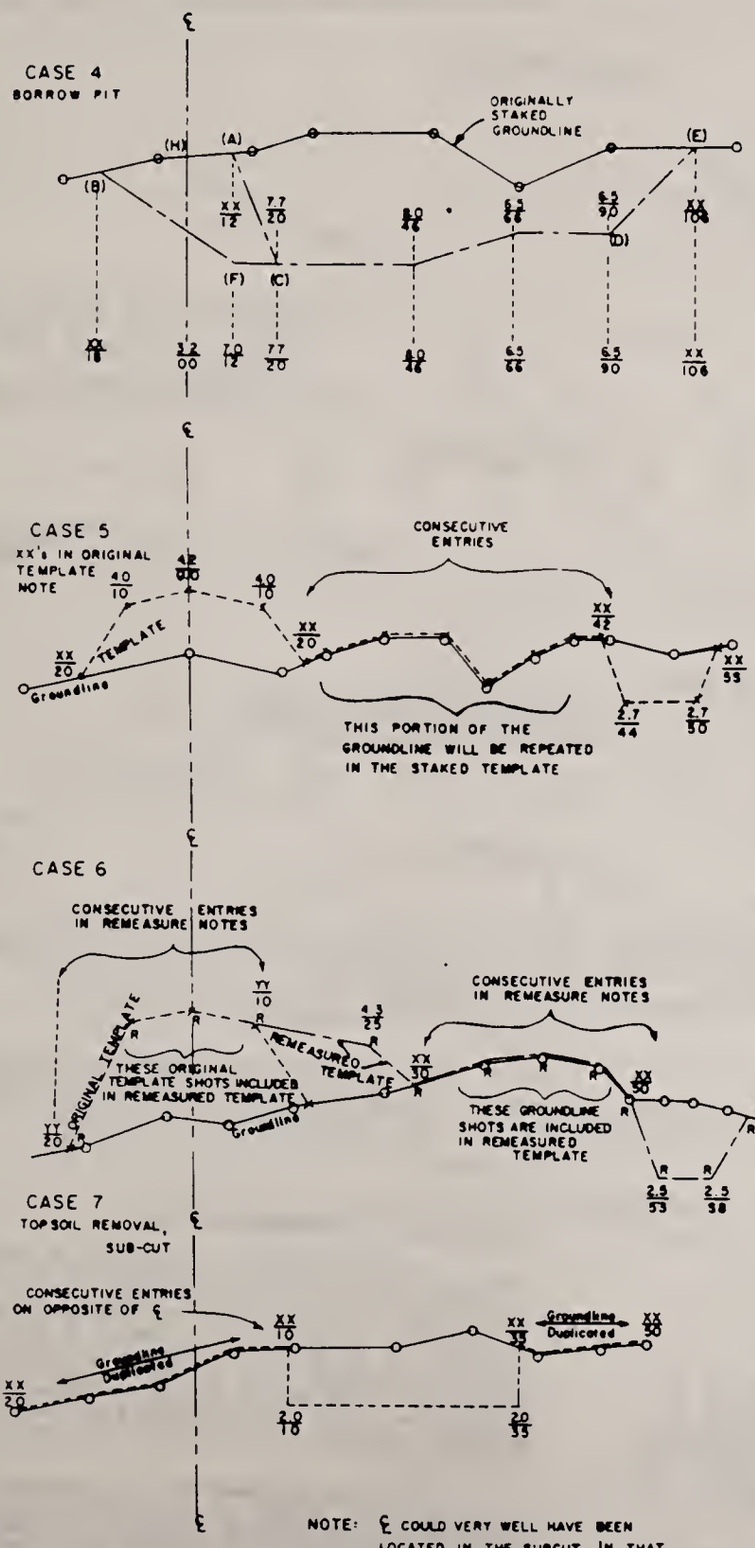
THE LAST SHOT RIGHT AND LEFT, WHERE GROUND AND REMEASURE INTERSECT NEEDS DISTANCE ONLY, PROVIDING THE REMEASURE SECTION IS COINCIDENT WITH AN ORIGINAL GROUNDLINE SECTION AND FURTHER PROVIDING THAT ORIGINAL GROUND NOTES GO FARTHER OUT THAN THE REMEASURE SECTION. IT IS BEST, INSTEAD OF ENTERING A ROD READING, TO WRITE "XX" AS SHOWN.

NOTICE THE TWO CONSECUTIVE "XX" READINGS AT XX/31 AND XX/69. THESE ENTRIES WILL CAUSE THE COMPUTER TO USE THE GROUNDLINE SHOTS BETWEEN THE "XX'S" AS TEMPLATE.

CASE 2. WHEN THE REMEASURE SECTION EXTENDS FARTHER FROM CENTERLINE, EITHER SIDE THAN THE ORIGINAL GROUNDLINE NOTES RECORD, THEN BOTH ROD READING AND DISTANCE ARE NECESSARY AT (M). THE COMPUTER WILL CONNECT POINTS (N) AND (M) AUTOMATICALLY AND DETERMINE THE END AREA. SUCH A READING AS 1.5/99.7 IS NECESSARY. THE USE OF XX/99.7 RESULTS IN NO PROGRESS.

WHEN THE ROADWAY SURFACE IS COVERED WITH GRAVEL (E.G.) AND IS INACCESSIBLE FOR REMEASURE READINGS, THE USE OF "YY" IS ACCEPTABLE, SUCH AS YY/52 AND YY/81 AT (L) AND (K). THE DISTANCE MUST BE THE SAME AS IN THE STAKED TEMPLATE NOTES. THE USE OF "YY" IN THE REMEASURE NOTES WILL TELL THE

Figure 9-7 (Continued)
Cross Sections for Remeasuring


CASE 4
BORROW PIT
ORIGINALLY STAKED GROUNDLINE
CASE 5
XX's IN ORIGINAL TEMPLATE NOTE
CONSECUTIVE ENTRIES
TEMPLATE
Groundline
THIS PORTION OF THE GROUNDLINE WILL BE REPEATED IN THE STAKED TEMPLATE
CASE 6
CONSECUTIVE ENTRIES IN REMEASURE NOTES
CONSECUTIVE ENTRIES IN REMEASURE NOTES
ORIGINAL TEMPLATE
REMEASURED TEMPLATE
THESE ORIGINAL TEMPLATE SHOTS INCLUDED IN REMEASURED TEMPLATE
Groundline
THESE GROUNDLINE SHOTS ARE INCLUDED IN REMEASURED TEMPLATE
CASE 7
TOPSOIL REMOVAL, SUB-CUT
CONSECUTIVE ENTRIES ON OPPOSITE OF ℄
Groundline Duplicated
Groundline Duplicated
NOTE: ℄ COULD VERY WELL HAVE BEEN LOCATED IN THE SUBCUT. IN THAT CASE XX LOCATION AND USE WOULD BE SIMILAR TO PREVIOUS CASES.

COMPUTER TO USE THE STAKED TEMPLATE NOTES BEGINNING WITH THE FIRST "YY" AND ENDING WITH THE NEXT "YY". (BEGIN YY/52. END YY/81). ALL ACTUAL REMEASURE READINGS (ROD/DISTANCE OR XX/DISTANCE) MUST BE FARTHER FROM CENTERLINE, EITHER SIDE, THAN A "YY" READING.

THE USE OF YY READINGS IS NOT PERMISSIBLE IF THE FINISHED ROADWAY IS NOT IN CONFORMITY TO THE ORIGINAL TEMPLATE.

CASE 3 - A, B, & C. THIS ILLUSTRATES ANOTHER SITUATION THAT COULD HAPPEN ON EITHER SIDE OF CENTERLINE. THE LEFT SIDE, CASE 3-A, NEEDS REMEASURE BUT THE RIGHT SIDE DOES NOT, BECAUSE IT WAS CONSTRUCTED IN CONFORMITY TO THE ORIGINAL TEMPLATE. THIS IS INDICATED BY THE SUGGESTED TYPICAL NOTES. LIKEWISE THE READING AT (F) COULD BE XX/57 INSTEAD OF 4.3/57. CASE 3-B, IS SIMILAR TO CASE 3-A. REMEASURE IS REQUIRED ONLY ON THE RIGHT SIDE. CASE 3-C, ILLUSTRATES REMEASURE ON BOTH SIDES OF CENTERLINE.

CASE 4. THIS ILLUSTRATES A BORROW PIT THAT WAS ORIGINALLY CROSS-SECTIONED ON BOTH SIDES OF A BASE-LINE OR CENTERLINE. WHEN EXCAVATION WAS COMPLETED, THE REMEASURE SECTION LOOKED LIKE ACDE. "XX" CAN BE USED AT (E), XX/106 AND AT (A), XX/12.

IF THE REMEASURED SECTION WERE REPRESENTED BY BFCDE, THEN "XX" COULD HAVE BEEN USED AT (B), AS XX/18 or 4.0/18, AS THE ENGINEER DECIDES.

CASE 5. THIS ILLUSTRATES THE USE OF "XX'S" IN THE ORIGINAL TEMPLATE NOTES. NOTICE THAT "XX'S" ARE CONSECUTIVE ENTRIES AND ARE BOTH ON THE SAME SIDE OF CENTERLINE.

CASE 6. IS AN EXAMPLE OF THE JOINT USE OF "XX" AND "YY".

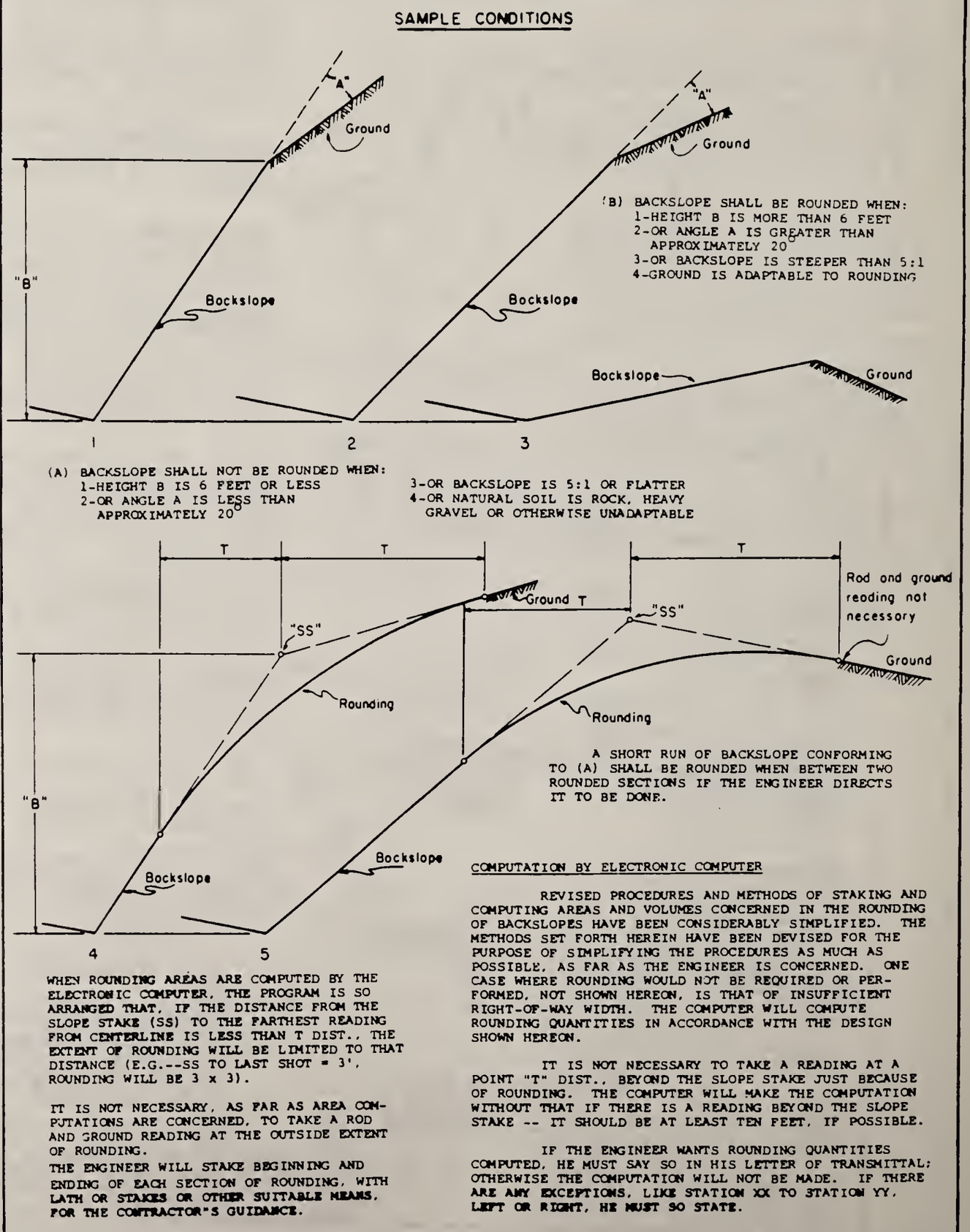
CASE 7. SHOWS THE USE OF "XX" FOR TOPSOIL REMOVAL, SUB-CUT, ETC.

NOTE: ONLY THOSE ENTRIES SHOWN ON THE EXAMPLE DRAWINGS (CASES 1-7) HAVE TO BE INCLUDED IN THE ENGINEER'S ACTUAL NOTES.

REMEMBER

1. "XX" MAY BE USED AS A ROD READING ANYWHERE ON THE SECTION.
2. "XX'S" MAY BE RECORDED CONSECUTIVELY IN THE CROSS-SECTION NOTES.
3. "XX" CAN BE USED ANY NUMBER OF TIMES ON THE SAME SIDE OF CENTERLINE PER SECTION.
4. "YY" CAN BE RECORDED IN REMEASURED TEMPLATE NOTES ONLY.
5. "YY'S" MAY BE CODED IN PAIRS ONLY.
6. "YY" MAY LIE ANYWHERE ON THE STAKED TEMPLATE AS LONG AS IT IS USED ONLY ONCE ON THE SAME SIDE OF CENTERLINE.

Figure 9-8
Backslope Rounding



(A) BACKSLOPE SHALL NOT BE ROUNDED WHEN:
1-HEIGHT B IS 6 FEET OR LESS
2-OR ANGLE A IS LESS THAN APPROXIMATELY 20°
3-OR BACKSLOPE IS 5:1 OR FLATTER
4-OR NATURAL SOIL IS ROCK, HEAVY GRAVEL OR OTHERWISE UNADAPTABLE

(B) BACKSLOPE SHALL BE ROUNDED WHEN:
1-HEIGHT B IS MORE THAN 6 FEET
2-OR ANGLE A IS GREATER THAN APPROXIMATELY 20°
3-OR BACKSLOPE IS STEEPER THAN 5:1
4-GROUND IS ADAPTABLE TO ROUNDING

A SHORT RUN OF BACKSLOPE CONFORMING TO (A) SHALL BE ROUNDED WHEN BETWEEN TWO ROUNDED SECTIONS IF THE ENGINEER DIRECTS IT TO BE DONE.

WHEN ROUNDING AREAS ARE COMPUTED BY THE ELECTRONIC COMPUTER, THE PROGRAM IS SO ARRANGED THAT, IF THE DISTANCE FROM THE SLOPE STAKE (SS) TO THE FARTHEST READING FROM CENTERLINE IS LESS THAN T DIST., THE EXTENT OF ROUNDING WILL BE LIMITED TO THAT DISTANCE (E.G.--SS TO LAST SHOT = 3', ROUNDING WILL BE 3 x 3).

IT IS NOT NECESSARY, AS FAR AS AREA COMPUTATIONS ARE CONCERNED, TO TAKE A ROD AND GROUND READING AT THE OUTSIDE EXTENT OF ROUNDING.

THE ENGINEER WILL STAKE BEGINNING AND ENDING OF EACH SECTION OF ROUNDING, WITH LATH OR STAKES OR OTHER SUITABLE MEANS, FOR THE CONTRACTOR'S GUIDANCE.

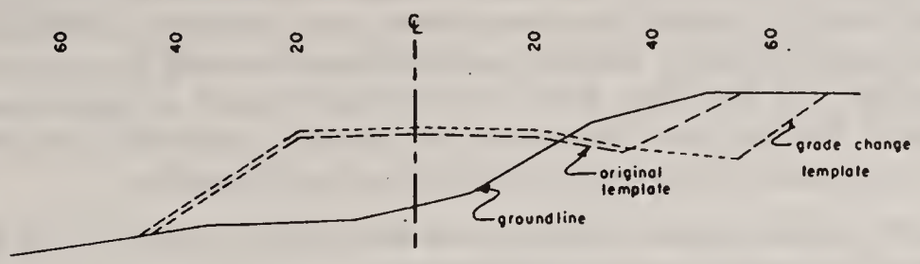
COMPUTATION BY ELECTRONIC COMPUTER

REVISED PROCEDURES AND METHODS OF STAKING AND COMPUTING AREAS AND VOLUMES CONCERNED IN THE ROUNDING OF BACKSLOPES HAVE BEEN CONSIDERABLY SIMPLIFIED. THE METHODS SET FORTH HEREIN HAVE BEEN DEVISED FOR THE PURPOSE OF SIMPLIFYING THE PROCEDURES AS MUCH AS POSSIBLE, AS FAR AS THE ENGINEER IS CONCERNED. ONE CASE WHERE ROUNDING WOULD NOT BE REQUIRED OR PERFORMED, NOT SHOWN HEREON, IS THAT OF INSUFFICIENT RIGHT-OF-WAY WIDTH. THE COMPUTER WILL COMPUTE ROUNDING QUANTITIES IN ACCORDANCE WITH THE DESIGN SHOWN HEREON.

IT IS NOT NECESSARY TO TAKE A READING AT A POINT "T" DIST., BEYOND THE SLOPE STAKE JUST BECAUSE OF ROUNDING. THE COMPUTER WILL MAKE THE COMPUTATION WITHOUT THAT IF THERE IS A READING BEYOND THE SLOPE STAKE -- IT SHOULD BE AT LEAST TEN FEET, IF POSSIBLE.

IF THE ENGINEER WANTS ROUNDING QUANTITIES COMPUTED, HE MUST SAY SO IN HIS LETTER OF TRANSMITTAL; OTHERWISE THE COMPUTATION WILL NOT BE MADE. IF THERE ARE ANY EXCEPTIONS, LIKE STATION XX TO STATION YY, LEFT OR RIGHT, HE MUST SO STATE.

Figure 9-9
Grade Change



Sample original staking notes.

Template			$\frac{10.4}{20}$		$\frac{10.0}{0}$		$\frac{10.4}{20}$		$\frac{13.4}{35}$		
Ground	$\frac{30.3}{68}$ R.P	F16 6 $\frac{27.0}{44.9}$ $1\frac{1}{2}$:1	$\frac{25.5}{35}$	$\frac{24.5}{10}$	F12 2 $\frac{22.2}{0}$	$\frac{20.0}{10}$	F1.2 $\frac{11.6}{26.0}$	$\frac{8.5}{30}$	$\frac{3.4}{50}$	C10.0 $\frac{3.4}{55.0}$ 2:1	$\frac{3.4}{76}$ R.P

SAMPLE GRADE-CHANGE NOTES

USE THE FOLLOWING PROCEDURE ONLY WHEN GROUNDLINE NOTES HAVE ALREADY BEEN PUNCHED

TEMPLATE	F18.0 $\frac{27.4}{47.0}$ $1\frac{1}{2}$:1	$\frac{9.4}{20}$	$\frac{9.0}{0}$	$\frac{9.4}{20}$	$\frac{12.4}{35}$	$\frac{14.4}{55}$	C11.0 $\frac{3.4}{71.5}$ $1\frac{1}{2}$:1

THIS ILLUSTRATES THE ENTRY OF THE TEMPLATE NOTES, AND THESE ONLY, IN AND ON ENTIRELY DIFFERENT PAGES OF THE NOTEBOOK. THE GROUNDLINE NOTES ARE NOT AMENDED IN ANY WAY. THE SLOPE STAKE READINGS FOR THE TWO OUTSIDE CATCHES ARE ENTERED INTO THE TEMPLATE BLOCK RATHER THAN INTO THE GROUNDLINE BLOCK. THE INSIDE CATCH AT 26.0' RIGHT COULD BE ENTERED INTO THE NEW TEMPLATE NOTES, BETWEEN 20' AND 35' RIGHT, IF THE ENGINEER SO DESIRES.

NOTATION MUST BE MADE, IN THE ORIGINAL NOTES, THAT A GRADE CHANGE HAS BEEN MADE.

THE NEW TEMPLATE NOTES MUST BE PROPERLY IDENTIFIED AND SUPPLEMENTED BY SUCH INFORMATION AS STATION, GRADE, H.I., AND ANY OTHER PERTINENT DATA. ANY H.I. MAY BE USED FOR THE REVISED TEMPLATE SINCE THE MACHINE WORKS WITH TRUE ELEVATIONS. THE SAME H.I. WAS USED HERE FOR EASE OF COMPARISON ONLY.

IF REVISED QUANTITIES ARE REQUIRED, SEND THE NEW NOTES TO HELENA FOR COMPUTATION. THEY WILL BE BLENDED WITH THE ORIGINAL NOTES.

Marking Slope Stakes

It is extremely important for the information shown on construction stakes to be concise, readable, and clearly understood by contractors. Because contractors may have projects in other parts of the State, consistency among the highway survey crews promotes understanding of the information being conveyed by everyone. Print the required information neatly on the stakes, paint them, and set them properly. Tilt them away from the centerline of survey at approximately 30 degrees from perpendicular. Face the printed side toward the centerline. On the back side print the station identification. If a great deal of information is required, use two slope stakes.

Cut and fill stakes should be marked with the stationing, depth of cut or fill, the slope and distance to the hinge point (shoulder or ditch bottom).

It is recommended that the contractor be given a copy of the final staking notes. The notes show the location of the catches and the like, which makes the grade setter's job a lot easier.

Fill Stakes

Place fill stakes at the fill catch points, and show the fill heights and distances to referenced points of the roadway (centerline, shoulder, hinge point, etc.) See Figures 9-10 and 9-11 on the next two pages.

The computer catches the slope stakes according to the fill height chart. If the fill height is borderline, the slopes may vary back and forth between stations: 2 to 1 and 4 to 1, for instance. In most cases, the designer corrects the situation and revises the slope staking book to provide a consistent slope through a fill area. You should review such situations and make adjustments where necessary to provide the most pleasing appearance.

Cut Slope Stakes

Mark cut slope stakes to bottom of ditch or back of ditch, both points and elevations being the same. In normal cut sections the bottom of ditch is the lowest elevation and the toe of the backslope.

Mark the cut stake with the cut depth to ditch bottom, the distance from centerline, and the horizontal-to-vertical slope ratio (i.e. 2:1). Figures 9-12 through 9-15 show examples of cut slope stakes.

Stake shallow cuts and transitions from cut to fill with the "daylight" stake — marked "DL." Usually, this stake does not go out the full distance of the backslope cut. Stake it either level with the ditch bottom or lower than the ditch bottom. If you stake it level with the ditch bottom, mark it with DL, F/0.0 to back of ditch, the distance from centerline, and the ditch distance from centerline. An example is shown in Figure 9-16.

Reconstruction

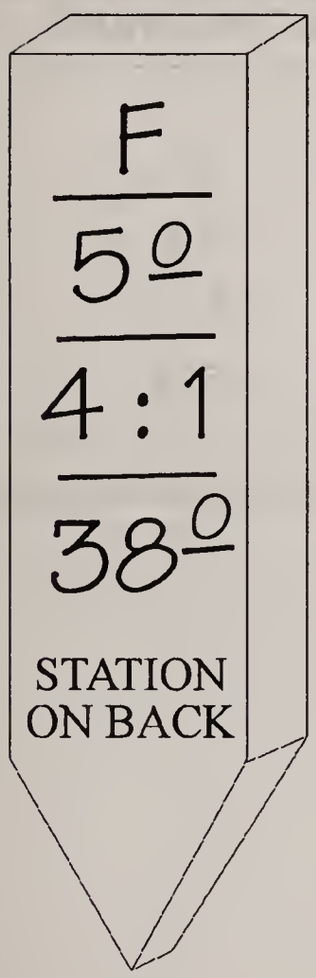
Many highway projects are reconstructed on existing alignment. Much of the staking of cuts, fills, and appurtenances can be done as described above. Other cases, however, present unique problems, particularly for the location and marking of construction control staking.

Road Approaches, Dikes, Etc.

Most road approaches and small dikes will be constructed from a few guide and reference stakes. Where it is necessary to stake an approach or dike, treat it as a roadway using centerline, shoulders, and slope stakes. The quantities may be included in the roadway mass.

Figure 9-10
Slope Stake for Normal Fill Section

RECOMMENDED SLOPE STAKE



INFORMATION FROM SLOPE STAKE BOOK

SLOPE STAKE
F
5.0
4 : 1
38.0
HP @ 18.0

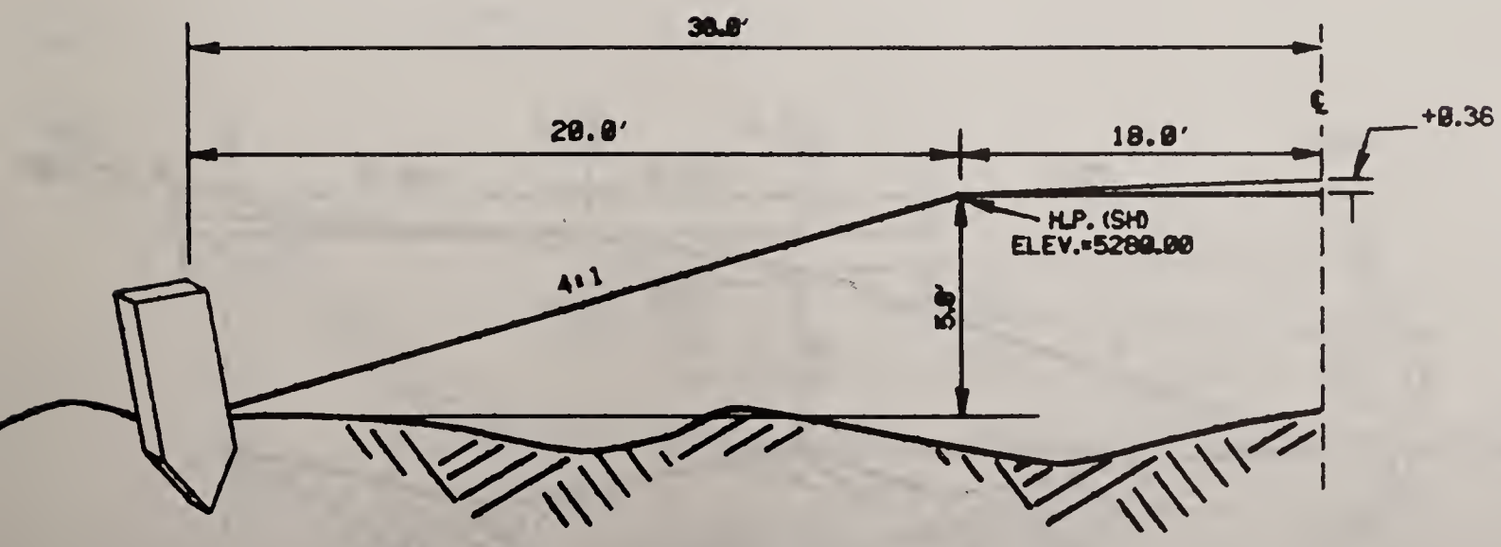
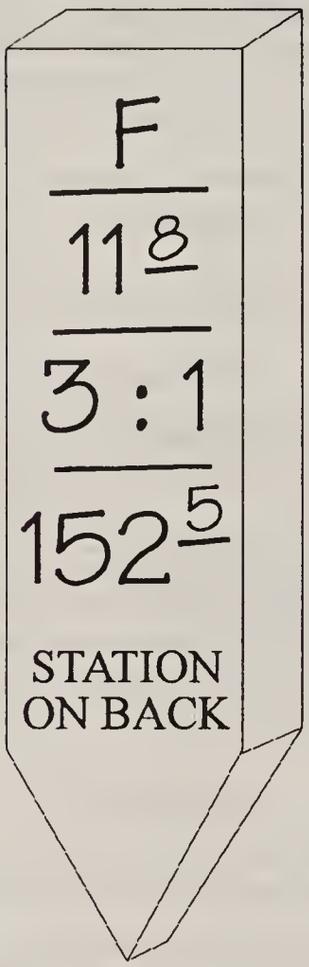


Figure 9-11
Slope Stake for Fill Section with Safety Shoulder

RECOMMENDED SLOPE STAKE



INFORMATION FROM SLOPE STAKE BOOK

SLOPE STAKE
F
11.8
3 : 1
152.5

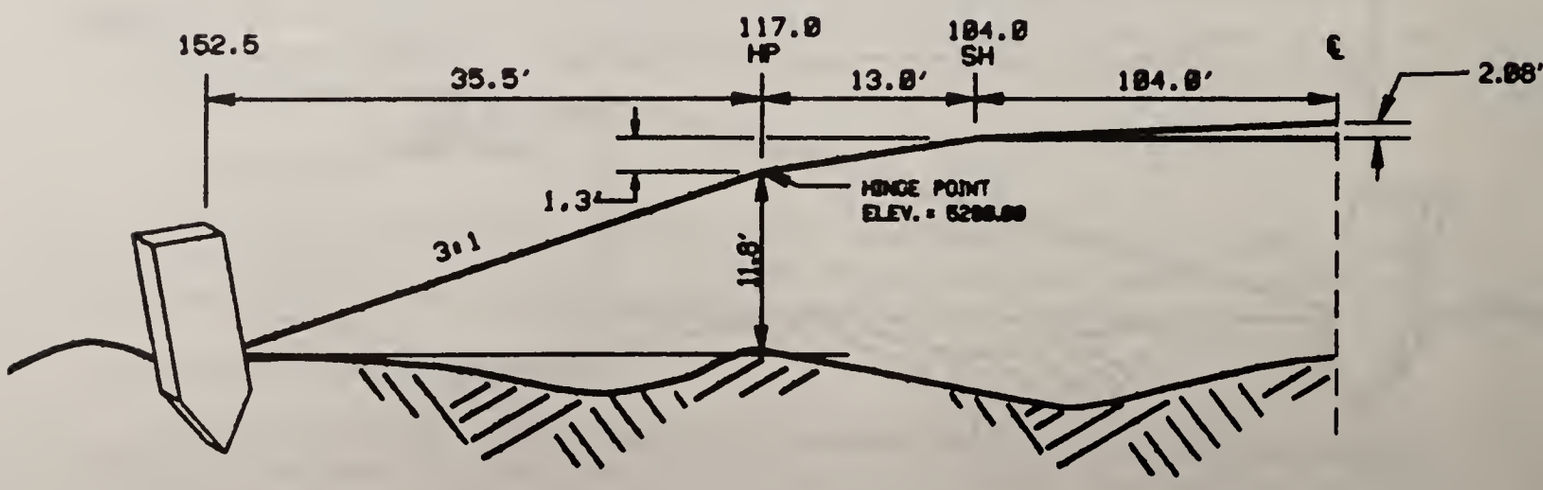
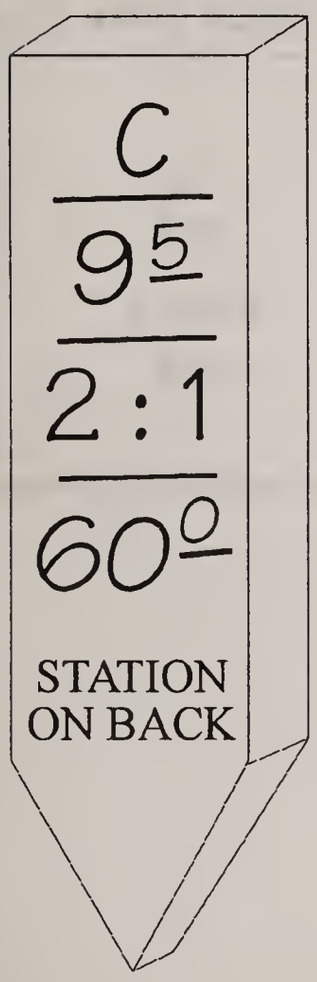


Figure 9-12
Slope Stake for Normal Cut Section — Example 1

RECOMMENDED SLOPE STAKE



INFORMATION FROM SLOPE STAKE BOOK

Slope Stake
C
9.5
2 : 1
60.0

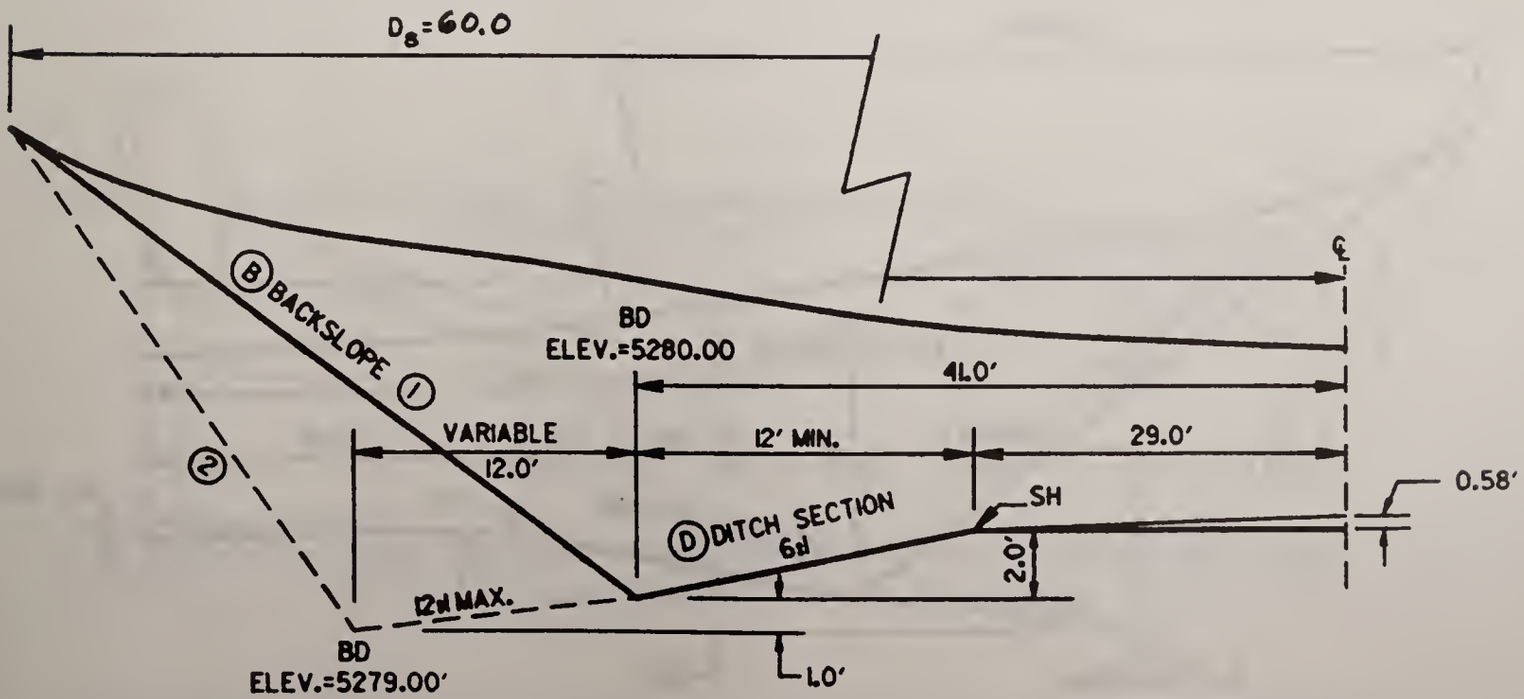
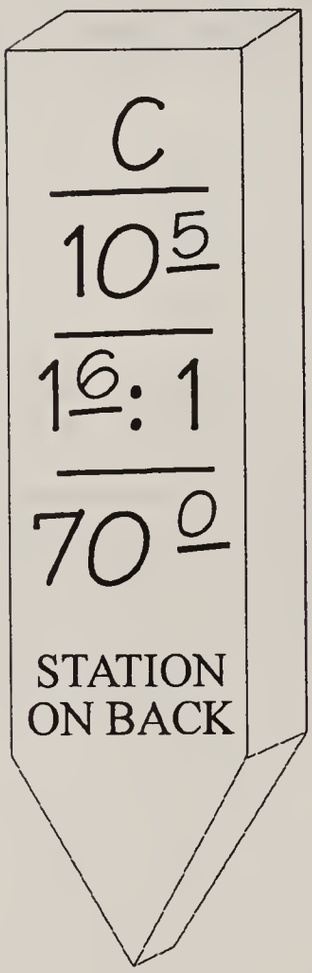


Figure 9-13
Slope Stake for Normal Cut Section — Example 2

RECOMMENDED SLOPE STAKE



INFORMATION FROM SLOPE STAKE BOOK

Slope Stake
C
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1.62 : 1
70.0

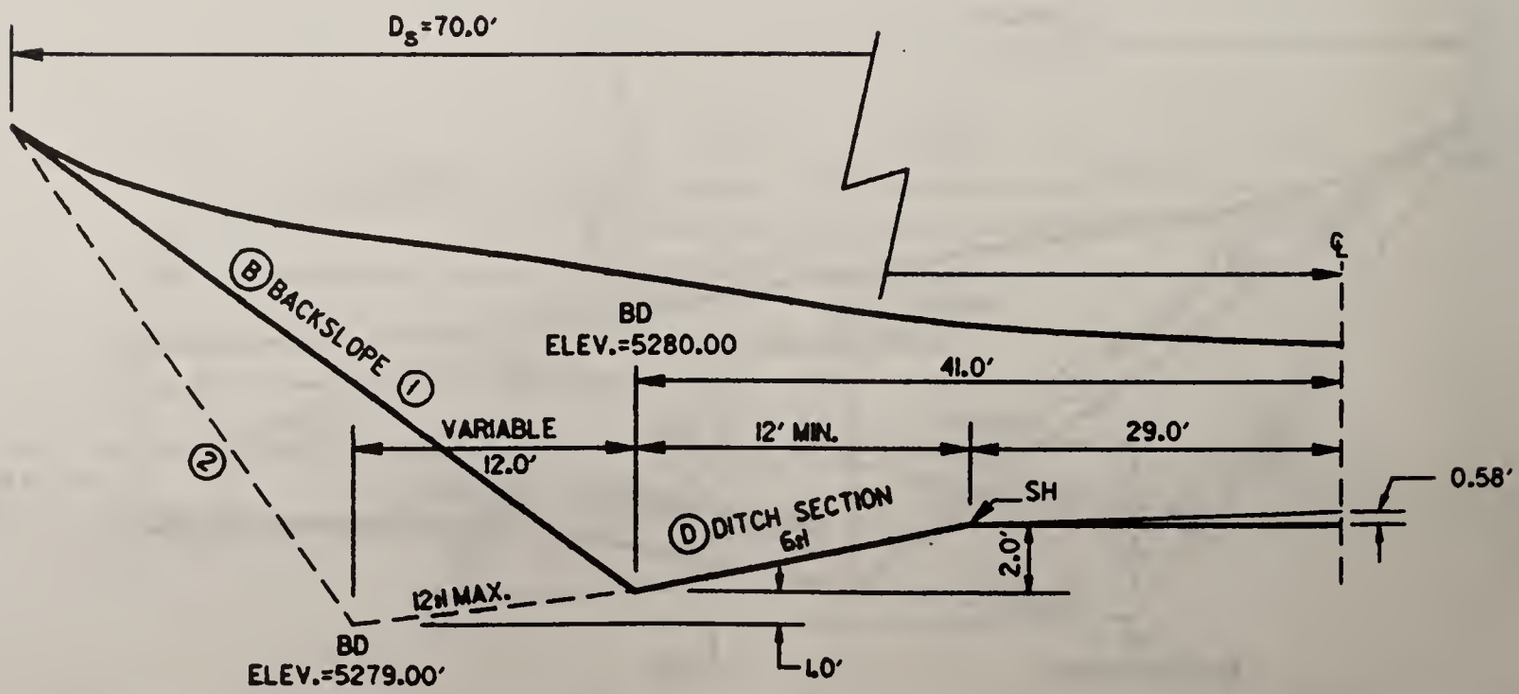
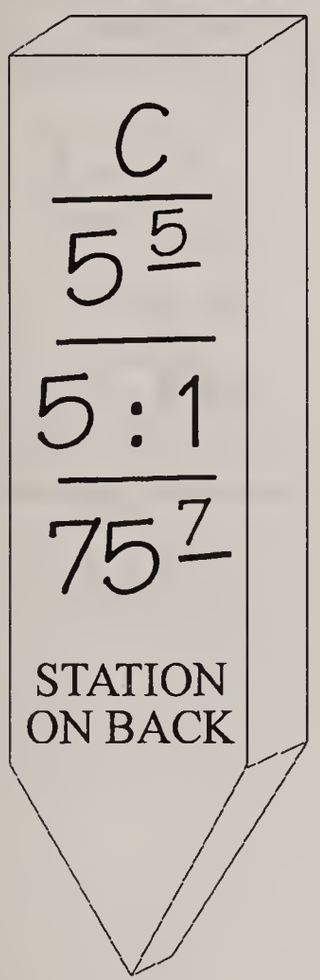


Figure 9-14
Slope Stake for Normal Cut Section — Example 3

RECOMMENDED SLOPE STAKE



INFORMATION FROM SLOPE STAKE BOOK

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5.04 : 1
75.7

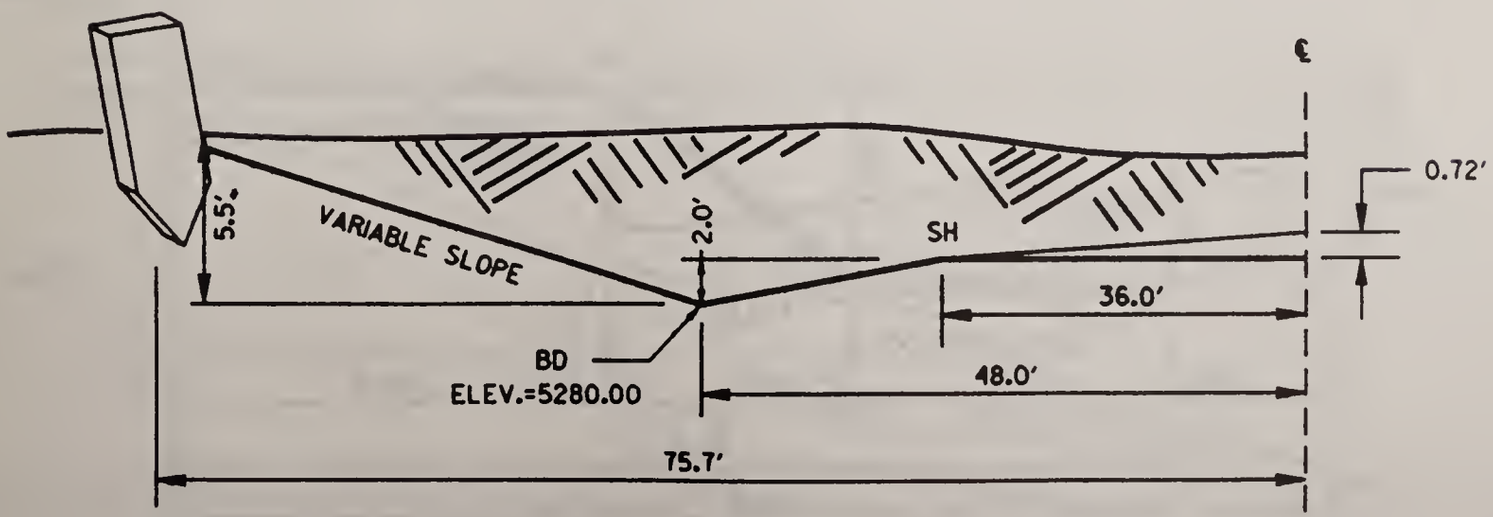
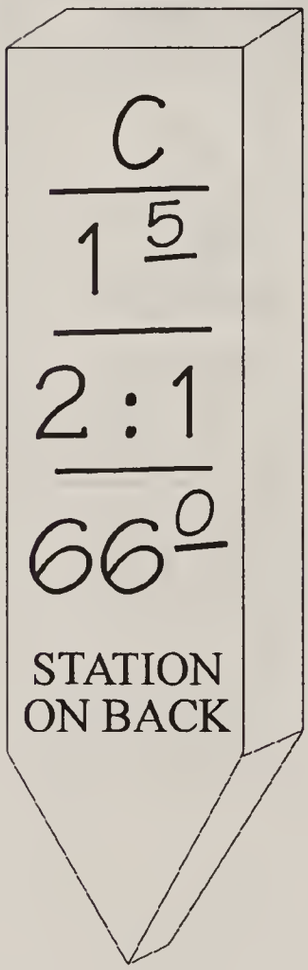


Figure 9-15
Slope Stake for Cut Section with Flat Bottom Ditch

RECOMMENDED SLOPE STAKE



INFORMATION FROM SLOPE STAKE BOOK

Slope Stake
C
1.5
2 : 1
66.0

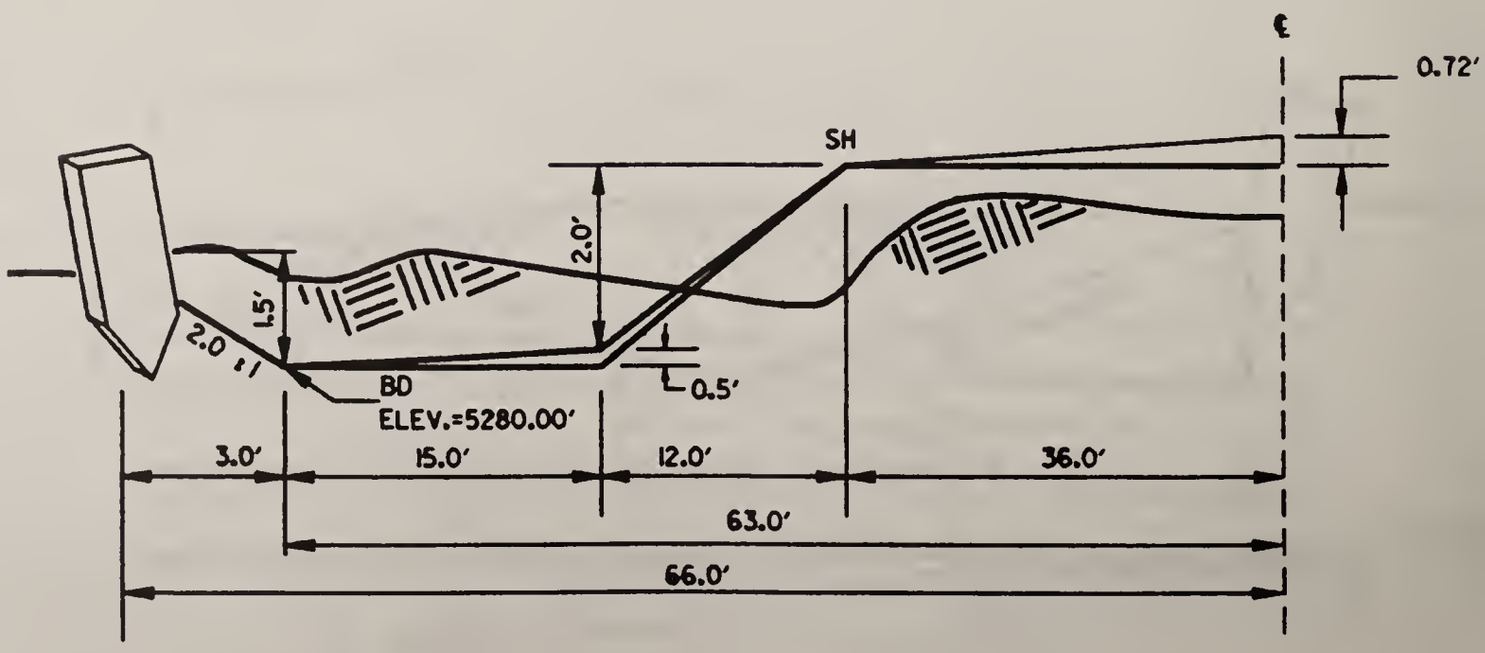
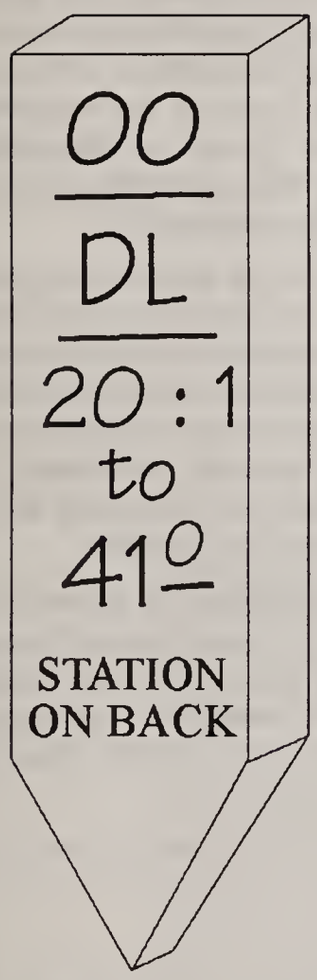


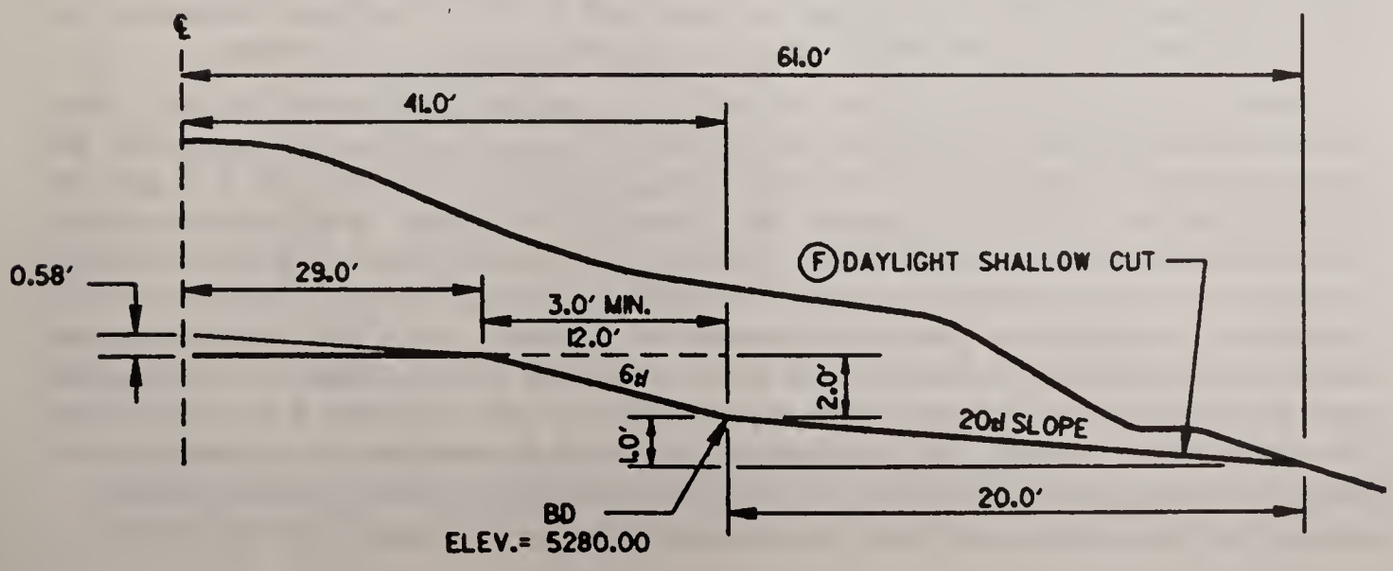
Figure 9-16
Slope Stake for Daylight Section

RECOMMENDED SLOPE STAKE



INFORMATION FROM SLOPE STAKE BOOK

Slope Stake
0.0
61.0
DL
20 : 1
to
41.0



Staking Borrow Pits

Frequently, borrow material is used to maintain a more uniform grade line and to construct interchange ramps in locations where roadway excavation material is not readily available. One of the primary considerations in removing material from a borrow site is determining how much material has been removed for roadway construction and where it was placed. Other considerations involving borrow sites are: topsoil removal and replacement, proper drainage, and appearance after the borrow material has been removed. Clear definitions of the borrow limits around the perimeter of the site are necessary to comply with the intent of the plan description and the wishes of the landowner as indicated on the agreement of permit. Borrow areas should be screened from the traveling public by the natural terrain or a row of trees. Borrow sites that are not screened should have their side slopes blended with the natural rolling ground line to provide a neat and pleasing appearance.

The level datum for borrow sites is to be tied in with the roadway bench marks where possible. Where borrow pits are located adjacent to the roadway, the roadway cross sections may be extended for complete coverage of the borrow site. Where it is not practical to tie the borrow site elevations in with the roadway level datum, at least two bench marks should be established outside the construction operations and referenced to an assumed elevation. The borrow site notes should contain a sketch of the borrow location including fences, baseline stationing, witnesses, references, bench marks, buildings, borrow limits, north arrow, a description of the section, township, range and other pertinent information that would allow another person to reestablish or carry on the work.

Topsoil is to be removed to the required depth, stockpiled and replaced after the borrow material has been excavated and pit neatly dressed. The topsoil quantities are to be kept separate from other excavated materials. This may require cross sectioning and computing before the topsoil material is removed, after the topsoil is removed, and again after all the borrow material has been removed. Topsoil quantities computed in this way will preclude claims for increased quantities that can be exaggerated by the contractor when no firm quantities or measurements exist.

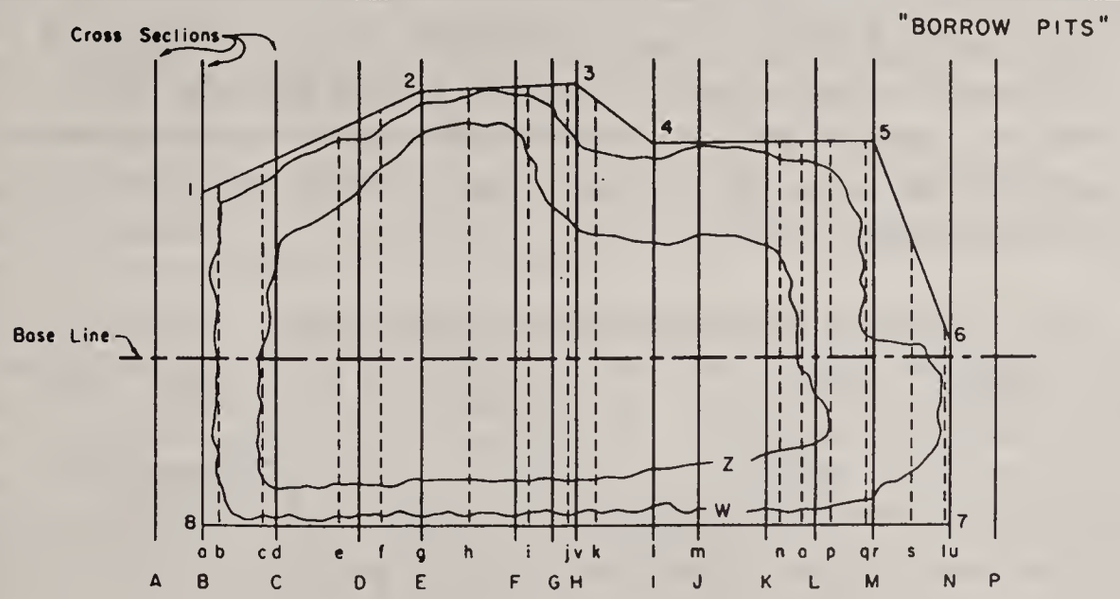
Examples of different methods of staking borrow sites may be found in Figures 9-17 and 9-18.

Finish Grade Stakes

The operation of construction staking is not complete until the roadway, ditches and other related facilities have been completed to the design section. Finishing stakes, popularly called bluetops, are set to line and grade as the roadway progresses from rough to finish. The roadway centerline is set with a transit and chain, and the shoulder stakes are measured perpendicular to centerline.

Line and grade control stakes will be set when the rough grading is sufficiently complete to allow finishing operations. Job conditions and the contractor's intended operations are factors that will determine the most economical method of establishing the required line and grade. It is generally helpful, at the contractor's request, to place lath with cut and fill markings at reasonable intervals to allow the contractor a more firm indication of the need for finishing prior to setting the bluetops. However, it is the contractor's responsibility to complete the rough grading of the roadway to within a half-foot or so of the true grade before bluetops are requested. It will help contractor-engineer relations to set rough stakes or laths, but this practice should not take precedence over other pressing work such as setting final bluetops where they are required in other locations. It is well to discuss with the contractor how and when rough-grading stakes will be established so the staking crew's schedule and the contractor's operation will complement each other and thereby minimize delays.

Figure 9-17
Borrow Pit Cross Sections — Example 1



THE MEASUREMENT AND COMPUTATION OF QUANTITIES INVOLVED IN BORROW PITS OR BORROW AREAS CAN BE HANDLED IN VARIOUS MANNERS. THE SAME PROCEDURES CAN BE APPLIED TO STOCKPILES. ONE LINE COMMON TO ALL METHODS IS BASELINE OR CENTERLINE. WHETHER SUCH A LINE TRAVERSES THE APPROXIMATE CENTER OF THE AREA OR IS OFF TO ONE SIDE IS OF MINOR CONSEQUENCE. MOST ENGINEERS PREFER A CENTERLINE OR BASELINE NEAR CENTER. TWO METHODS WILL BE DISCUSSED ON THIS PLATE.

(1) THE ENGINEER ESTIMATES THE BOUNDS OF THE POSSIBLE BORROW AREA, RUNS OUT A CENTERLINE OR BASELINE AS SHOWN ON THE SKETCH, AND DETERMINES THAT CROSS-SECTIONS WILL BE REQUIRED AT VARIOUS PLUSSES DENOTED A, B, C, ETC., N AND P, EACH OF THE LENGTH SHOWN. WHEN THE EXCAVATION IS COMPLETE, HE RETURNS AND RECROSS-SECTIONS ON THE SAME PLUSSES OR LINES AND PROBABLY FINDS IT NECESSARY TO ADD A FEW SECTIONS. HE PROBABLY WOULD VOID THE SECTIONS AT A AND P. HE WOULD, IN THIS CASE, NEED ADDITIONAL SECTIONS AT b, c, e, f, h, i, j, k, n, o, p, q, s and t. HE WOULD HAVE TO INTERPOLATE A GROUNDLINE FOR EACH OF THESE. HE WOULD THEN FIGURE THE END AREA OF EACH SECTION AND FROM THOSE FIGURES DETERMINE THE VOLUME. THIS METHOD HAS BEEN USED FOR MANY YEARS. THE CROSS-SECTIONS HERE WOULD BE THE SAME AS IN ROADWAY CROSS-SECTIONING.

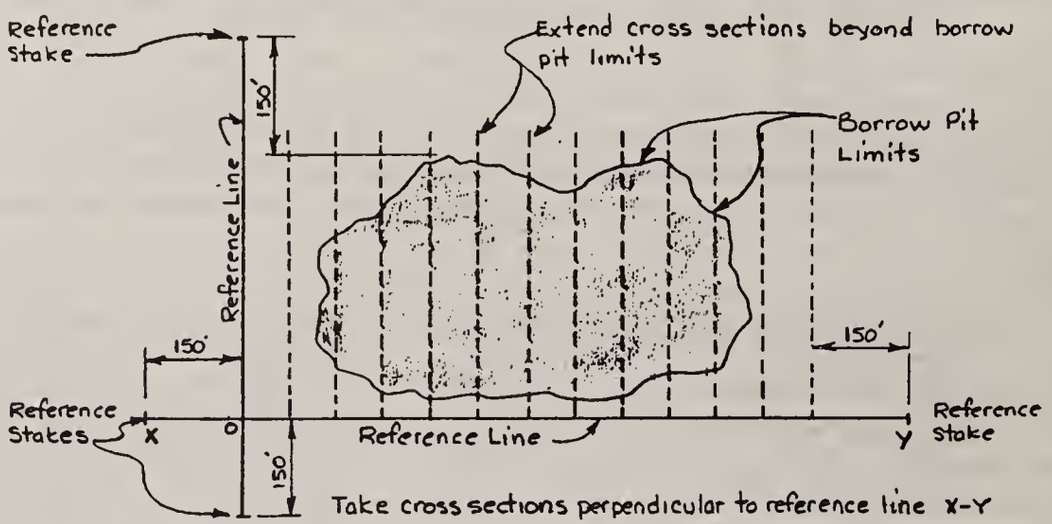
(2) THE ENGINEER ESTIMATES THE BOUNDS OF THE POSSIBLE BORROW AREA, RUNS OUT A CENTERLINE OR BASELINE AS SHOWN ON THE SKETCH, AND DETERMINES THAT CROSS-SECTIONS WILL BE REQUIRED AT VARIOUS PLUSSES DENOTED A, B, C, ETC., N AND P, EACH OF THE LENGTH SHOWN. WHEN THE EXCAVATION IS COMPLETE HE RETURNS AND SIZES UP THE SITUATION. HE NOTES THAT HE WILL NOT HAVE TO REMEASURE TO THE SAME EXTENT HE ORIGINALLY CROSS-SECTIONED BECAUSE THE BOUNDS OF THE PIT ARE LESS THAN HE EXPECTED (REPRESENTED BY LINE W: Z IS THE APPROXIMATE BOTTOM). HE THEN LAYS OUT, ON THE GROUND, THE BOUNDARY LINE "1-2-3-4-5-6-7-8-1". THE BREAKS IN THE BOUNDARY LINE, 2, 3, 4 AND 5, SHOULD BE ON ORIGINAL CROSS-SECTION LINES THAT ARE TO BE REUSED FOR REMEASUREMENT. HE NOTES THAT HE DOES NOT NEED THE PLUSSES AT A AND P. HE NOTES THAT HE WILL NEED CROSS-SECTIONS AT a,b,c,d,e,f,g,h,i,j,v,k,l, m,n,o,p,q,r,s,t, and ü TO PROPERLY COMPUTE THE EXCAVATION. HE PROCEEDS TO AMEND THE ORIGINAL GROUNDLINE NOTES BY CROSSING OUT OR CIRCLING THE READINGS BEYOND THE EXTREMITIES OF THE BOUNDARY LINE "1-2-3-4-5-6-7-8-1", AND RECORDING ELEVATIONS WHERE THE LINES C, E, H, I, J AND M INTERSECT THE NEW BOUNDARY LINE; ALSO THE ELEVATIONS AT 1 AND 8 ON LINE B AND 7 AND 6 ON LINE N. THEN HE PROCEEDS TO CROSS-SECTION THE BORROW PIT ON THE LINES NOTED ABOVE, BEING VERY CAREFUL TO TERMINATE EACH SECTION ON THE LINE "1-2-3-4-5-6-7-8-1". HE NOTES A PILE OF WASTED EXCAVATION IN THE CORNER NEAR THE LINE "5-6" WHICH HE ALSO CROSS-SECTIONS ALONG WITH THE EXCAVATION. THE METHOD OF DETERMINATION OF NET QUANTITIES WILL VARY CONSIDERABLY FROM THAT USED IN (1). THIS SYSTEM IS PARTICULARLY ADAPTABLE TO THE ELECTRONIC COMPUTER. A COMPUTER BASE PLANE IS ESTABLISHED A FOOT OR SO ABOVE THE HIGHEST POINT RECORDED IN EITHER ORIGINAL OR REMEASURE NOTES. THEN THE DATA CONCERNING THE ORIGINAL GROUNDLINE IS PROCESSED AND THE VOLUME OF AIR BETWEEN THE BASE PLANE AND ORIGINAL GROUND (LIMITED BY THE LINES "1-2-3-4-5-6-7-8-1") DETERMINED. NEXT, THE REMEASURE DATA IS PROCESSED AND THE VOLUME OF AIR DETERMINED BETWEEN THE BASE PLANE AND THE REMEASURED GROUND (AGAIN LIMITED BY THE LINE "1-2-3-4-5-6-7-8-1"). THE DIFFERENCE IN VOLUMES IS THE NET AMOUNT OF EXCAVATION. THE PILE OF WASTE WILL BE COMPUTED AND DISCOUNTED BUT THE VOLUME WILL NOT BE DISCERNIBLE.

IF THE CONTRACTOR WERE TO EXPAND TO A LARGER AREA THAN ORIGINALLY CONTEMPLATED, THEN THE GROUNDLINE NOTES SHOULD BE EXTENDED ACCORDINGLY. THE FINAL PROCEDURE WOULD BE AS OUTLINED ABOVE.

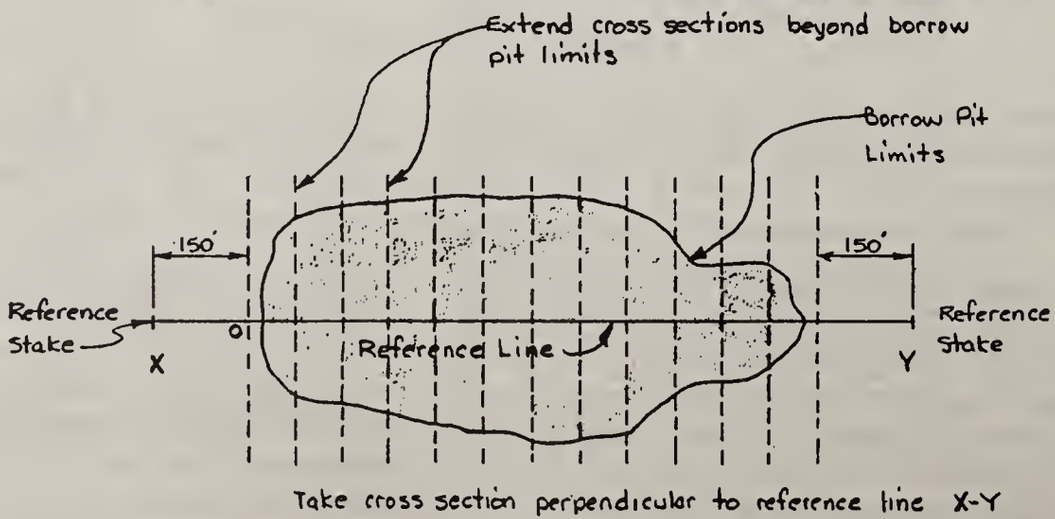
Figure 9-18
Borrow Pit Cross Sections — Example 2

Take cross sections at each intersection of lines forming a 25' grid network. Use other points, as necessary, to show the true ground surface. Distances or dimensions shown below are for the surveyors guidance. Use judgement to fit the survey to the natural terrain.

1. Typical Borrow Excavation Site



2. Borrow From Old Embankments or Long Rows of Material



Finish grade stakes are set at 50-foot intervals on centerline and each shoulder for narrower roads. On wider roads with very wide sections such as the interstate, five lines of bluetops will be necessary — centerline, each shoulder and about halfway between centerline and shoulder. It may be necessary to set blue tops at 25-foot intervals around curves, depending on the radius and where transitions or changes in superelevations occur. The bluetops are set to grade with a level. The top of the stake is driven to the proper elevation and marked with crayon or paint to indicate that its top is at grade. Bluetops should never vary more than 0.05 foot from the true elevation.

Care should be exercised to provide a smooth transition where the roadway grade meets an existing bridge or other changes in elevation occur. Changes in elevation should be drawn out over a long distance to make the transitions as gentle as possible.

Grade and line for concrete paving are usually established along the shoulder line by a series of stakes set at 50-foot intervals, to 0.01 foot accuracy and offset a uniform distance from construction machinery. The contractor may then place iron stakes to support a wire line at a uniform height above the true grade and to the same degree of accuracy as the original grade control. When the wire line has been properly set and checked, small deviations may be observed by sighting along the wire. Corrections must be made, when needed, before accepting the position of the wire as accurate.

Ditch and channel flow lines may also need to be bluetopped, especially where runoff grades are very flat.

Bridge Construction Surveys

Responsibilities

The bridge staking method is designed to provide an independent check of all structure layout. This check will benefit both the contractor and the Department in that delays and expenses incurred due to improper location of structure units will be held to a minimum. This method will also aid in maintaining engineering costs at acceptable levels.

Department Responsibilities

The centerline will be marked by clearly identified points set in the immediate vicinity of each structure unit under construction. These points will be in addition to the primary survey controls ordinarily established for references. These points are to be set such that typical skilled contractor personnel will be able to proceed with the remaining layout without the services of a skilled surveyor. Sufficient controls will be set so the contractor can use batter boards, string lines or simple instrument setups to shoot straight lines from one point to another.

The State will furnish bench marks which will include:

- cut stakes for footing excavation,
- beam seat elevations for bush hammer leveling and/or shimming,
- elevations at span tenth points for setting deck slab forms, and
- grade on structural steel splices.

The Department is responsible for the accuracy of the bench marks and points described above in accordance with Article 105.08 of the Montana *Standard Specifications for Road and Bridge Construction.*

Contractor Responsibilities

The contractor is responsible for completing the remaining layout and setting and maintaining the location of excavation, piling, cofferdam, forms and the like in accordance with these points.

Checking and Inspection

It is ***mandatory*** that project personnel physically check the contractor's layout for line and grade on the following items, particularly at the stage of work shown:

- cofferdams — when the ring is set and prior to driving sheet piling;
- footing excavation — prior to beginning excavation;
- piling — prior to driving piles;
- forms — prior to authorizing the contractor to order and place concrete; and
- embedded items — prior to authorizing the contractor to order and place concrete.

In some cases, it is in the best interests of the Department to perform intermediate checks prior to placing large quantities of reinforcing steel where moving the form would result in a major operation of dismantling, shifting of the reinforcement or additional structure excavation. Discretion should be exercised in making checks so they do not become a substitute for the mandatory checks described above or become a substitute for the layout that is the contractor's responsibility.

It is recognized that occasions will arise when demands on project personnel will exceed their capacity to perform all required inspections at the particular time desired by the contractor. In these cases, it shall be the responsibility of the field project manager or the person in charge to require the contractor to set priorities for the work. ***In no case*** will work be allowed to continue without the required inspections. The need for additional inspection personnel and/or more efficient procedures and scheduling is indicated if it becomes necessary to continually set such priorities.

Preliminary Procedure

- Check dimensions on bridge plans prior to staking. In particular, check elevations from finished grade down through the deck slab, girder, shoes, crossbeams, columns and footings. Check span lengths, skew angles, and the like for horizontal control.
- Review road or other plans for construction features that could affect the layout and location of references for the structure — especially any special embankment requirements.
- Check alignment and stationing of roadway centerline as staked in the field. Be certain that lines and stations already staked on the ground are as shown on the plans.
- Determine whether bench marks shown on the plans and those proposed for establishment of vertical control are in place and usable.
- Plan layout and referencing to provide control of work with the required accuracy in the most economical manner. Place references where they will serve their intended purpose for as long as required — where they are readily accessible and where they are secure from construction operations, if such is possible. Do not place references in the center of a ramp road or in a place where a portion of the substructure will not be visible.
- Before construction work may begin on any structure, layout referencing and field checking of primary horizontal and vertical control must be complete.

State Plane Coordinates

Most construction and reconstruction projects are being designed using a horizontal and vertical control traverse. At the present time, these control traverses are based on a local or assumed horizontal datum base. The vertical datum is either NGVD 1929 or NAVD 1988. GPS surveys will utilize the Montana State Plane Coordinate System and NAVD 88 exclusively.

The current local coordinate datum is a ground level system that can be used for everything on the project with no correction factors required. When state plane coordinates are used, the datum for the state plane is below ground level. Therefore, a factor between ground measurements and grid measurements must be used.

Structure plans need to show ground measurements, so that the fabricators can use the plan measurements. Therefore, on projects that use the state plane coordinate system for horizontal datum, a local structure coordinate system at ground level is used for the actual structure staking. The local structure system is equated to the state plane coordinate system at one point on centerline and uses the same basis of bearing.

Horizontal Control — General

Due to terrain and other site conditions, it is not practical to adhere rigidly to any one standard method of layout and referencing. The following basic principles of good engineering measurement will be used to produce work that is within the following permissible limits of error:

- Cast-in-place structures — 0.02 foot per 100 feet or 1 in 5,000
- Prestressed beam structure — 0.01 foot per span or 1 in $\frac{\text{span length}}{0.01}$
- Steel structures — 0.01 foot per span or 1 in $\frac{\text{span length}}{0.01}$ (centerline bearing to centerline bearing)

  Examples:

	50-foot span	Accuracy required = 1 in 5,000
	100-foot span	Accuracy required = 1 in 10,000
	200-foot span	Accuracy required = 1 in 20,000

- ***Layout shall be checked by a method independent of the method used initially.*** This will be entered in a set of notes clearly showing the method of checking used, all computations, observed errors, and the accuracy of the original layout compared with the check.
- Reference points should be established by methods that will permit the reestablishment of the layout to the original accuracy.
- References will be established in sufficient numbers and in the proper locations to permit accurate and timely control of the work.
- Reference points will be clearly identified and flagged on the ground. Notes shall be prepared such that a person not familiar with the project will be able to readily locate and use the reference system and reestablish points destroyed or disturbed. ***Record layout and references in field notes.***
- At least one line of references, located beyond the outermost portion of substructure units, should be established to permit a check of span lengths along the reference line to detect divergence from plan lines.

- Chaining — The following are the effects that various factors have on chaining:

Factor	Deviations[1]	Makes Chain
Temperature	15° F.	Long or short
Tension	15 lb. (1½ lb. chain)	Long or short
Slope	1.4 feet	Short
Horizontal Line	1.4 feet	Short
Wind	0.6 foot bow in center	Short
Plumbing (breaking chain on steep slope)	1.5 feet to 0.1 foot per 100-foot chain length	Long or short

- Setting points — The following factors should be considered in choosing materials and methods for survey points:

  + Length of expected need. Do not expend a lot of effort in setting points required for a short time.

  + Stakes. These include the usual 2-inch x 2-inch hubs and 1-inch x 2-inch stakes. Generally hubs are driven flush with the ground. Soil conditions, both present and future, will normally determine the type of stakes. If unusual conditions are encountered, acquisition of materials other than those normally supplied is justified as each point represents a considerable investment in time money.

  + Guard stakes. Clearly identify the point on the guard stakes and replace as required. Check with railroad authorities before placing any stakes, lath or the like on railroad right of way. Any type of flag is generally unacceptable to them.

Horizontal Control — Tangent Dry Land Structure

The procedures for staking this type of bridge are:

- Establish centerline of structure, centerline of roadway or other control line as required. Reference this line with two points on either end of the bridge. Set witness points outside the construction limits.
- Establish points at the intersection of centerline of structure with centerline of bearings or centerline of bents of all the various units of the substructure. Place guard stakes on these points to clearly identify them. Example: Bent No. 2 Westbound — Centerline of Bent at Centerline of Roadway — Station 484+75.00.
- Reference the points established in the above step. Use method of turning angles and chaining distance consistent with accuracy required. Separate references a distance sufficient to minimize effects of normal sighting and instrument setup errors. Include the following:

  + line referenced,

  + bent number, and

  + distance from centerline of structure.

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[1]These deviations will cause an error of 0.01 foot per chain length.

Record reference points in notes. Include information such as the distance from centerline of structure, topography useful to approximately locate points, ties, relationship to structure and type of point set.

- Perform an independent check of the layout. Enter in the notes a sketch of the method used, computations, observed errors, and errors expressed as a ratio. For example: On skewed structures, provision should always be made to allow check chaining of span lengths at a reference line outside the outermost portion of the bents. This is a necessary check to assure that the bent centerlines are not incorrectly diverging or converging.
- The first four steps above constitute the primary control and must be performed before construction begins on any portion of the structure. If construction is allowed to proceed on a portion of a structure before these steps are accomplished, it becomes extremely difficult to complete the layout in accordance with good practice.
- Should the situation arise out of absolute necessity, the following procedure shall be used to allow construction before all primary controls have been established:
  + Establish the location of one sub-unit (bent, pier, or abutment). This sub-unit becomes the anchor point for the layout of the rest of the structure.
  + Proceed with the layout of the rest of the structure by direct measurements from the anchor point sub-unit.
  + The use of this method requires that establishment of construction controls proceed in order from the substructure unit first located.
  + This method requires that direct measurement be made to check each new substructure unit against those already constructed.
  + This procedure shall also be used in instances where primary controls cannot be reestablished because references have been destroyed or disturbed.
- If the check shows that layout and references are within limits of permissible error, proceed with the layout of construction control points. In the interest of consistency and uniformity, and in keeping with policy, the following procedure is recommended:
  + Lay out and establish points on centerline of footings and abutments, sufficient to permit the contractor to locate the footing excavation limits, lay out piling, and set footing and column forms by means of batterboards and string lines or other methods selected by the contractor.
  + It is required that the contractor lay out the footing excavation limits, piling, set forms on line and the like from the points furnished. That layout shall then be checked by the Department crew prior to placement of the items. This will provide an independent check of the work.
  + After the first substructure unit has been constructed, the location of subsequent units should be checked in reference to previously constructed units by careful direct measurements to ensure proper fit of superstructure units. This is particularly critical for crossbeams. Measurements should take into account the effects of slope, temperature and tension.

Horizontal Control — Dry Land Structure on Curve

The procedures for staking a bridge on a curve are:

- Establish bridge chord or other control line as required. Reference with two points on either end of the bridge. Set witness points outside the construction limits as necessary to permit re-establishment of the line.
- Establish points at intersection of bridge chord or control line and centerline of bearing or centerline of bent. Identify these points with guard stakes and in the notes with the same information as a structure on a tangent.
- Reference the points established in the previous step. In making layouts it will be necessary to perform computations for various distances to utilize the system shown. However, use of this system will result in an independent check of angles and of span distance on centerline and at the reference lines.
- ***Always perform an independent check of the layout.*** Follow the procedure as stated in the previous section for structures on tangents.
- Pay particular attention to offset distance from the chord line to the centerline of bent or centerline of footing. Check plan distances in the office on paper prior to layout and check completed field layout. Layout errors occur too often.

Vertical Control — Construction Grades

At least two bench marks should be used in setting or checking construction grades. This will detect possible settlement of bench marks as well as calculation and observation errors.

The procedures for vertical control of construction grades are:

- The following are the limits of permissible error for the various structural units—

Point or Portion of Structure	Limit of Permissible Error
Bench marks	Refer to Chapter 4
Footing cross sections	± 0.05 foot of plan elevation
Footing cut stakes	± 0.02 foot of plan elevation
Footing elevations	± 0.02 foot of plan elevation
Column elevations	± 0.02 foot of plan elevation
Tops of crossbeams	± 0.01 foot of plan elevation
Beam seats, structural steel, splices, curbs, deck slab forms	± 0.01 foot of plan elevation
Beam 10th points, tops of decks, guard angles, expansion joints	± 0.005 foot of plan elevation

- For structure excavation cross sections, take enough shots to permit quantity calculations to be made. Precision required for shots is the nearest 0.10 foot.
- Set stakes showing cut to bottom of footing. Read the rod to the nearest 0.01 foot and show the cut to 0.01 foot. Indicate on the stakes where the cut is measured from.

- Check to see that grades for footing and column forms have been set to within 0.02 foot of plan elevation.
- Grades for the tops of crossbeams and beam sets should be within 0.01 foot of plan elevation.
- A rod level should be used in cases where it is necessary to use a high rod where waving the rod is not possible or practical.
- Turning points should be chosen or set that will not settle between foresight and backsight shots.
- In checking and setting grades for construction, it is very desirable to take shots on points of known elevation of other units of the structure already completed.

Fill Settlement Check Elevations

Whenever the sequence of work calls for a specific settlement period to elapse after the roadway embankment is completed, there is no guarantee that the settlement will occur or be completed by the end of the specified time. It merely allows the fill a period of time in which the major part of the expected settlement or consolidation can occur. The following steps should be taken whenever settlement elevations are being established and shall start immediately upon completion of the fill at the bridge end:

- Establish enough points so if several are destroyed, sufficient points remain to complete the record.
- Set as many of the points as practical in positions where they are not likely to be destroyed by construction operations.
- Tie levels between two established bench marks. Do not depend on one because it can be affected by settlement of nearby fill or may be disturbed.
- Take and record readings at least once per week. When three or four weeks pass with no movement noted, the frequency may be reduced to once every second week. Submit copies of all readings to the Construction Bureau.

With an accurate record available for review, it may be possible that a portion of the stipulated fill settlement period can be waived. If settlement is still occurring at the end of the specified period, full details should be submitted for review.

Structure Settlement Check Elevations

Whenever structure settlement is noted on completed items of work, the Construction Bureau should be notified immediately, and a settlement record systemshould be initiated. This will be done by establishing permanent marks on or over the substructure units by marking an "X" on the guard angles, floor joints or concrete near the face of both curbs and on centerline at each and every bent or pier. Take and record readings at least once per week until three or four weeks pass with no movement noted. Then continue readings every second week until you are satisfied that settlement has ended. Submit copies of field records to the Construction bureau. You will be advised as to corrective action to be taken. Place bench marks on the ends of all newly placed caps of bents and piers, and record the elevations to the nearest 0.01 foot — as soon after the concrete is placed as practical. This will provide information as to whether differences in elevations that may be noted later are due to settlement or are due to a possible error in elevation during construction. If the difference in elevation is actually due to settlement, it is important to know whether it took place rapidly or slowly and whether it is still occurring.

Structures Involving Railroads

On railroad grade separations, the stationing of the mainline tracks or other railroad reference lines shown on the plans should be carefully checked to assure that the proper lateral clearance will be provided.

The first step in locating a structure over a railroad is to establish the point where the centerline of the roadway or the centerline of the structure intersects the centerline of the mainline tracks. The rest of the structure will be laid out from this point disregarding any discrepancy in roadway stationing of structure units.

Take elevations of the top of rail at sufficient locations in the vicinity of the structure to assure that proper vertical clearance is provided. This information is also helpful for shoring and cribbing plans and in case a question arises over the effect construction activities are having on the tracks.

The following are some precautions to be observed in stakeouts near or on railroads:

- Watch for trains.
- Do not allow the steel chain to drop across the tracks because such contact activates the railroad signal system and will result in an unpleasant visit from railroad officials in a very short while.
- Do not allow the chain or any other equipment to come in contact with high-tension wires. This will lead to the need for a new survey crew.

Construction Surveys for Small Drainage Facilities

General

The proposed flow line elevations for outlet ditches, sewers, channel changes, culverts and other drainage facilities are shown on the plans. However, during the time interval from plan completion to contract award, nature or man may have caused changes in the existing drainage course. Therefore, culverts and other drainage facilities, as planned, may not be in exactly the correct position. It is a good idea to make a thorough review of the existing drainage course compared with the location shown on the plans. Profiles of existing drainage are to be taken if there is any doubt whatsoever.

Existing culvert or storm sewer flow lines through adjacent highways, railways or other facilities may effectively control flow of water through the intended construction zones. Drainage facilities through the new roadbed may require adjustment to conform with in-place drainage facilities. ***All drainage must have an outlet.*** Good design of drainage facilities is truly a science, but common sense and good judgment are an absolute necessity if water is to be properly drained without causing property damage, floods or undue erosion.

Pipe Culverts

Almost every culvert must be staked and installed before grading can begin, and the staked length must be known so the contractor can order a reasonably accurate quantity. Although the location, type, size, length and elevation of the flow line are shown on the plans, all conditions affecting these requirements should be checked before the culvert is staked. Any major change must be authorized before installation. Culverts should be staked and the staking information made sufficiently clear so there will be no error on the part of the contractor or inspector due to misunderstanding. Skew angles, as shown on the plans, should correspond with field conditions, but if they do not, corrections must be made so the installation will conform with field conditions.

The staked length of culvert pipe must fit the slope, and generally should conform with a multiple of the commercial length available for that size of pipe. A hub and tack is set at each end of the pipe centerline a sufficient distance beyond the construction limits to prevent their destruction. A guard stake placed over each hub and tack should show the cut or fill to flow line and the distance offset from the end of the culvert. Other information relative to the length, type and size of pipe needed for the installation may also be shown on the guard stakes. After the stakes have been set, a check should be made of the total fall and direction of flow. A gradient of 0.3 percent is normally the minimum grade that will carry sediment. The culvert flow line elevation (invert) should be staked about 0.2 foot lower than the flow line elevation of the inlet and outlet channels to help minimize piping, obtain a more solid bedding, and provide more opening for small flows.

Concrete Box Culverts

The use of concrete box culverts is quite limited. In staking box culverts, these guides should be followed.

The plans for concrete box culverts should be thoroughly reviewed and checked prior to the stakeout. The initial step in staking box culverts is setting reference lines parallel to the centerline of the structure. Hub and tack references placed sufficiently outside the construction area should be set at each end on the structure centerline and at convenient locations on the other reference lines. The need for reference lines is determined by the field project manager, but is based on the width, length and location of the culvert. The culvert centerline and a reference line to the face of the wingwalls should be staked.

Set finish grade stakes after excavation to the footing elevation. After the footing is in, the remainder of the structure layout can easily be marked by the contractor and checked by the inspector providing that a number of reference elevations are available and alignment is provided.

The staking method should be carefully explained to the contractor and the inspector by the field project manager.

Dikes and Ditch Blocks

Dikes will usually follow the roadway shoulder line to curving or parallel alignments. Stakes marking the extremities of the dikes are usually satisfactory. An adequate number of stakes should be set to delineate all of the features of the dikes and to allow an accurate computation of earthwork volumes involved.

Staking of ditch blocks can be done by setting a stake on the shoulder. This stake will then designate the stationing of the ditch block and its height, length and side slopes. The side slopes of the ditch block should start at the inlet or pipe and extend about 10 feet on a slope of 10 to 1 or flatter. The height of the ditch block should be:

- about 1 foot above the top of the pipe,
- at subgrade elevation, or
- about 1 foot above the inlet elevation.

Drop Inlets

A single stake, hub or marker may be used to identify the center of the inlet structure, and two or more hub-and-tack reference stakes may be used to establish the structure centerline by marking the distance from the center of the structure to the hub-and-tack locations.

Drop inlets frequently must meet curbs already in place or other in-place structures and therefore must be accurately staked to avoid future expensive alterations. There is some flexibility in locating catch basins or curb inlets, but neither of these structures should be placed in the area of a crosswalk.

Curb, Gutter and Sidewalks

A reference line may be run behind the curb at a constant offset distance and permanently tied with hubs and tacks. Reference distances should be marked to the top, the back or the flow line of the curb, whichever method is convenient and compatible with the construction method. The vertical difference in the elevation between the reference point and the elevation of the lip of the curb should be included as well as the cut or fill to grade. The reference line stakes may be used on straight alignment. Such existing grade control points as intersecting streets, in-place sidewalks or in-place curbs and gutter must be used to modify the theoretical planned elevations.

Construction Surveys for Miscellaneous Items

Items in this group include fences, bin walls and retaining walls, traffic control devices, utility items, guardrail, right-of-way monuments, comfort stations and the like.

The degree of accuracy used in setting construction stakes for miscellaneous items must be consistent with the use of that item and should be adequate to establish the location. Some of the items may require a full complement of stakes precisely set; other items may require only a mark or a nail placed to indicate the correct location.

Fence

The latest right-of-way map is to be made available for use at the time fences are staked. Last-minute changes in right-of-way limits, that may not have been known at the time of original staking, may then be correctly included.

Stakes should be set at the right-of-way line and on right-of-way breaks and curves. Stakes should be visible from one to the next. An adequate number of stakes should be set at reasonable spacing to allow fence construction without extensive use of surveying instruments. Curved fence alignment may be staked in the usual manner, setting stakes at regular intervals. Layout of the fence line, to be consistent with the contract pay items, must be on a line parallel with the top wire of the fence and extend from end post to end post. This new measurement is intended to verify the actual length of fence in place.

Bin Walls and Retaining Walls

A satisfactory number of cross sections should be taken from a baseline offset to the bottom of the bin or retaining wall. The cut or fill from this reference line may then be calculated to other control points of the bin or retaining wall. Establish reference lines and set control points outside the construction zone to readily reestablish points along the wall.

Traffic Control Devices

Signs are staked at the locations shown on the plans with a lath, stake or hub. The sign is identified on the lath or stake. Signs may be moved a few feet one direction or another from the planned position where obstacles are encountered, but care should be taken in positioning signs so they are properly visible and will serve their intended function. Signs may be moved greater distances (10 feet or more) when their visibility will be impaired by trees, buildings, land forms or other permanent

obstacles after approval is received from the district construction engineer, FHWA engineer or the Construction Bureau. The severity of the move will dictate the need for consulting higher authority.

The Traffic Unit will furnish technical assistance, if needed, on projects containing such bid items as permanent signing, traffic signalization or lighting. The field project manager may request such assistance through the district construction engineer. In contrast to signs set in rural locations that may be moved to better fit field conditions, a lighting or signal project is intended to function at a specific location and has its structure designed for that location only. Changes in the design or location, even though these changes may be needed and will obviously fit, must receive the attention of the Traffic Unit through the Construction Bureau.

Utilities

Most utility moves, relocations or adjustments are made by the utility owners prior to construction, which generally confines the staking required of State forces to that necessary for establishing horizontal and vertical clearance controls. Utilities that are being installed, relocated or readjusted as a part of the contracted work will require staking necessary to provide alignment and grade in addition to horizontal and vertical clearance controls. A careful review should be made of the proposed roadway construction so adequate clearance is provided across road approaches and the main line, so the intended position of the utility does not conflict with use of other facilities.

A full survey party should not be used if one or two persons can do the job adequately. With proper handling and advance coordination, most of the utility relocation features can be set to require a minimum of resurveying.

Guardrail

Special installation instructions are shown on the plans and on standard drawing sheets for locating guardrail and guide post installations, but it is difficult for a designer to accurately pinpoint the locations for these facilities. Consequently, it is necessary to perform a field check of the locations just prior to staking. Adjustments may be necessary in the lengths and locations. The field project manager should obtain the proper authorization before proceeding with staking when large differences in quantities are encountered.

Several different staking techniques have been successfully employed in the past. The choice of which to use will be determined by the field project manager. Hubs and tacks or nails set for proper alignment and grade may be established from the offset line. Guardrail on tangents may be staked by marking each end of the run of guardrail, or the location of each post may be staked individually. No matter what staking method is used, the field project manager should insist on a project that, when finished, presents a satisfying appearance in alignment and grade.

Right-of-Way Monuments

Right-of-way monuments are to be 5/8-inch x 30-inch rebars with approved aluminum caps. The cap is stamped with the station, offset, R/W and the year. The cap will have a punch mark at the correct distance. Right-of-way monuments are set at the locations shown on the plans. This is at the PCs and PTs for simple circular curves, at the STs and TSs for spiral curves, at breaks in the right of way, and at the beginning and end of all projects.

A separate notebook will then be set up during construction to show the final locations of all right-of-way monuments and the distances to centerline.

The District has the discretion to set monuments on centerline instead of on the right of way. This option should be considered in those locations where there is a high probability the right-of-way

monuments and their reference monuments will be destroyed by farming, construction or the like. The centerline monument will consist of a 5/8-inch x 30-inch rebar and an approved 2-inch aluminum cap. The cap will be stamped with the station number and the year. The cap should be set below final grade. Right of Way will be informed so their plans are compatible with the monumentation.

Right-of-Way Reference Monuments

Reference monuments for the right of way are to be 5/8-inch x 30-inch rebars and approved 2-inch aluminum caps. The reference monument is set 3 feet inside the right-of-way monument (between the monument and centerline) on a line perpendicular to tangents or 90 degrees to a line tangent to curves.

Right-of-Way Reference Post

A 42-inch delineator post having a 4-inch by 5-inch right-of-way sign bolted to it is set 2 feet inside the right of way.

Monuments Located During Construction

During the process of monumentation of the record right of way, the crew may find evidence of the original monument. In these cases, do not set a new monument at the calculated position. Tie the existing monument using the procedures in Chapter Six. Right of Way should be notified so their plans are consistent with the monumentation in the ground. A metal locator should be used to search in the vicinity prior to setting a new monument at the calculated position.

Comfort Stations

Comfort stations require staking building locations and such items as drain fields, underground sprinkling systems, driveways, sidewalk, and locations for planting trees and shrubs.

A careful review of the plans for the building site and attendant facilities should be made before staking is begun. Baselines or reference lines should be established at the proper locations and their control points referenced to prevent destruction. Line and grade must be set for the footings of the building, for sewer facilities, and to provide a convenient reference for workers to establish batter boards and lay out the facilities.

Table of Contents

Chapter Ten — Hydraulic Surveys

Survey Data for Design of Waterways 10-1

Watershed Data (HYD-1, Section 1) 10-1
Area 10-2
Debris 10-2
Ice 10-2
Unusual Watershed Characteristics 10-3
Water Surface Elevations 10-3

Existing Structures (HYD-1, Section 2) 10-4

Erosion and Geology Data (HYD-1, Section 3) 10-4

Location Sketch (HYD-1, Section 5) 10-4

Waterway Cross Sections (HYD-1, Section 6) 10-4

Profiles (HYD-1, Section 7) 10-5

Plan (HYD-1, Section 8) 10-5

Irrigation Surveys 10-6

Urban Storm Drainage 10-7

Contributing Area 10-7

Outfalls 10-7

Settling Basin 10-7

Utilities 10-7

Water Supply 10-8

Water Wells 10-8

Water Information 10-8

Springs 10-9

Waste Water Disposal 10-9

Small Earth Fill Dams 10-10

Roadside Erosion 10-11

Figures

10-1 Blank Form HYD-1 10-13

10-2 Form HYD-1 — Example 1 10-15

10-3 Form HYD-1 — Example 2 10-17

10-4 Form HYD-1 — Example 3 10-19

10-5 Form HYD-1 — Example 4 10-21

10-6 Form HYD-1 — Example 5 10-23

10-7 Form HYD-1 — Example 6 10-25
10-8 Form HYD-1 — Example 7 10-27
10-9 Example Form HYD-2 — Water Well Information 10-29

Chapter Ten
Hydraulic Surveys

All hydraulic surveys are different and many times items will be encountered that are not discussed in this section. Contact the Hydraulic Unit to discuss the information that should be submitted for a particular hydraulic site.

The old saying, "A picture is worth a thousand words," is especially true when discussing a hydraulic survey. The need for adequate photographs cannot be over emphasized. A great deal of information can be submitted in photographs. Photographs should always be well labeled on the back.

Make any comments or recommendations that you feel might be pertinent to the hydraulic design. A short discussion of the hydraulic history of a site is often helpful in the hydraulic design.

Survey Data for Design of Waterways

To ensure that all of the watershed data is submitted, Form HYD-1 is provided to record the basic data for a watershed. A sample form is shown in Figure 10-1 on Page 10-13. Figures 10-2 through 10-8, starting on Page 10-15, show examples of completed HYD-1 forms. Other pertinent data should be submitted with Form HYD-1 on separate sheets.

Complete Form HYD-1 for all stream crossings with drainage areas of one square mile or more, and for all stream crossings with bridges in place. Form HYD-1 is not required for existing pipe crossings when photo mapping is available. Form HYD-1 should be filled out in ink or filmograph (plastic) lead to provide a more permanent record of the survey data.

The following paragraphs list and describe the watershed data required by Form HYD-1. The data for each item required on the form is placed on the appropriate blank completely and accurately. Additional sheets should be used when sufficient space is not available on the form.

All supporting documents, such as survey notes, photographs, etc., are submitted with Form HYD-1. All bench level notes must indicate the datum, e.g., NGVD29 or NAVD88. All photographs should be labeled, dated and referenced on the back of the photograph. Photographs should not be taken when the stream is frozen or the ground is covered with ice or snow, unless such conditions portray a situation that the surveyor feels should be brought to the attention of the Hydraulics Unit.

Some of the information requested will not be readily available and will require some research or consultation with appropriate people to obtain the required information.

Watershed Data (HYD-1, Section 1)

This section contains information about describing watersheds in terms that will be usable by the designer. Other items such as debris and ice are included because they have a direct bearing on the type of structure to be selected.

Area

The total drainage area of the watershed should be estimated to determine whether Form HYD-1 should be completed. If the total drainage area is near one square mile, or if the drainage area cannot be determined, the form should be filled out completely. The estimated drainage area is not required for crossings with bridges in place. The hydraulic designer will determine the actual drainage area so the estimated area is used only for determining the survey requirements.

Sometimes there will be parts of the total drainage area that do not contribute to the runoff from the basin. These may be low areas, swamps, lakes, etc. These areas should be determined as accurately as possible and the information provided on Form HYD-1 so the drainage area may be adjusted accordingly. If this area is significant, an explanation should be attached to the form.

Debris

Flood flow reaching a culvert or bridge nearly always carries debris that may be either floating material, material heavier than water, or a combination of both. Debris must be considered in the hydraulic design because it can be deposited at the culvert or bridge entrance and impair its operation. A thorough study of the extent and types of the debris originating in the drainage basin is essential for proper design.

The type of debris has been classified into the following groups:

- very light debris or no debris;
- light debris — small limbs or sticks, orchard pruning, and rubbish;
- medium debris — limbs or large sticks;
- heavy debris — logs or trees; and
- other — city trash, old car bodies, etc.

The group that best exemplifies the debris from the drainage basin should be indicated on Form HYD-1. If the "other" classification is checked a short description of the kinds of debris found should be attached. Possible future changes in the type of debris that might result from changes in land use in the drainage basin should also be noted. As an example, logging in a previously virgin area could change the nature of the debris problem from one of "medium debris" to "heavy debris".

An estimate of the quantity, as well as the type of debris, is needed by the designer so that adequate debris storage can be provided. Information on the types and quantities of debris resulting from past floods can be an invaluable guide in selection of the type of debris control structure. Such information may be secured from maintenance personnel, from inhabitants of the immediate area or by personal observation.

Ice

Ice conditions, like debris, have a direct bearing on the type of structure and substructure used. Ice can cause damage at hydraulic structures in two ways: (1) ice can exert high forces or pressures causing a structure to buckle or collapse, either by thermal expansion during freezing or by impact of large chunks of ice on the structure at high velocities; and (2) ice can plug the waterway causing flooding to upstream property and possible damage to the structure.

The potential for ice damage at a crossing should be determined and indicated on Form HYD-1 as either light, moderate, or severe. If it is determined that the ice damage could be severe, a

discussion of the type of damage and how it could be caused should be attached. Maintenance personnel and local residents may aid in establishing whether or not there is a potential ice problem.

Unusual Watershed Characteristics

Sometimes a watershed is encountered whose characteristics differ significantly from those expected for watersheds in that vicinity. When an unusual characteristic is encountered, it will be the responsibility of the survey personnel to write a detailed description of the unusual feature and attach it to Form HYD-1. Following is a brief discussion of several unusual characteristics that might be encountered and what information should be given about them.

It is difficult to make runoff predictions for streams that get a great deal of their flow from springs. When such streams are encountered, the location of the springs within the drainage basin and an estimate of their flow should be given. Because of the difficulty in predicting runoff for such a stream, descriptions of other crossings both upstream and downstream should be given. The following information should be given in the description: size of pipe or opening under the bridge, type of entrance, length of pipe, type of pipe, height of fill, and historical adequacy.

Dams can also affect the runoff and complicate runoff predictions. They should be adequately described so their effect can be considered. Large government dams need not be described because records for these dams are readily available. The small stock dams are of primary concern. The description of the dams should include the name of the owner and builder, the type of material (earth or concrete), height, location in drainage basin, approximate area of the reservoir when full, and a detailed description and dimensions of the spillway and outlet control works.

Water Surface Elevations

The water surface elevations should be measured at the centerline of the survey. If an existing structure makes it impossible to measure the elevations at the centerline, they should be measured at the upstream and downstream end or edge of the structure and a note added to Form HYD-1 indicating where they were taken.

The elevations of the water surface on the date of survey should be taken and shown on all of the cross sections in Section 6 of the form. The low water elevation should be the approximate elevation of the water surface at its lowest point during an average year. If the stream goes dry at some time during the average year, it should be so indicated. Local residents might be able to help in establishing a low water elevation.

The high water elevation requested on Form HYD-1 is the historic high water elevation. This elevation can be established in several ways. There may be visual signs such as drift lines or water stains that will indicate the high water mark. Local residents, Department maintenance personnel, county commissioners, and county road foremen (on secondary projects) will many times remember how high the water got at certain points and may help establish the high water elevation. Written records, such as newspaper stories, may also help establish the high water elevation. The dates and causes of high water should be given if they can be determined.

Establishing the location, nature and elevation at which damage would occur from upstream flooding is an extremely important part of this section. Some sites may have several damage elevations. The elevation and a brief description of the damage should be located in Section 8 (or Section 5, if the scale is better) of Form HYD-1.

If the stream being crossed contains game fish that must pass through the structure to spawn or for some other reason, this should be indicated.

Existing Structures (HYD-1, Section 2)

The purpose of the existing structure information is to aid in establishing the size of the proposed structure. The capacity of the old structure, together with the knowledge of how well it has carried past floods, aids in determining the size of the new structure. The existing structure may also influence the hydraulics at the proposed crossing if it is left in place.

The historical adequacy of the existing structure and the high water elevation can be determined by visual marks, by talking to local residents, and in some cases by old newspaper accounts. The high water elevation should be measured at the upstream edge of the structure.

Erosion and Geology Data (HYD-1, Section 3)

The information requested in this section is self-explanatory and will be used to determine what type of bank protection will be used and when to use it. If the scour is very severe, a short description giving depth, etc., should be attached to the form.

The channel stability information refers to the channel bottom and not the banks. A degrading channel is one in which the bottom is being eroded away and is lowering. An aggrading channel is one in which the water is depositing material and is building up.

Location Sketch (HYD-1, Section 5)

The purpose of the location sketch is to show the general topography of the crossing area. This sketch should show the stream meander and the location of all existing roadways, roadway structures and buildings in the area plus the locations and orientation of channel cross sections plotted in Section 6. The location sketch is not required for photo mapped projects.

Waterway Cross Sections (HYD-1, Section 6)

The channel cross sections are the most important part of the survey data collected. Care should be taken to see that they accurately describe the channel through a reach of from 500 feet upstream to at least 1,500 feet downstream. If there is not enough room on Form HYD-1 to plot the cross sections, the extra ones should be plotted on an additional sheet of cross-section paper and attached to the form. The location of each section taken should be indicated in Sections 5 and 8. On projects that are photo mapped, only the portion of the cross section that is below water is required.

NOTE: The Bridge Design Section requires channel cross sections at centerline of roadway and 20 and 40 feet right and 20 and 40 feet left of centerline of roadway for every roadway structure. The stream cross sections should extend beyond the flood plain on both approaches to all crossings where a bridge may be required. They should be shown in the notes only and should not be plotted on Form HYD-1.

Each section should be taken perpendicular to the direction of the flow and plotted looking downstream. Since the area of flow is determined from the cross sections, an improperly oriented section may produce a large error. ***Each section should be extended far enough to extend above the maximum possible flood.*** Sometimes this will require a cross section of a very wide flood plain, but this is information that is required and must be taken.

Another very important feature of a cross section is the location and classification of vegetation and streambed material. Methods of recording this information are indicated in Figures 10-2 through 10-8 starting on Page 10-15.

When an extensive flood plain is encountered, it may be necessary to plot the entire cross section using a small scale and replot the low-water portion of the channel to a larger scale so the more important features of this portion of the channel can be shown in more detail. An example of this method is shown in Figure 10-5 on Page 10-21.

Cross sections should be located:

- at distinct changes in stream bed slope;
- immediately upstream and downstream of locations where changes in discharge occur;
- to accurately describe variations in geometry, including abrupt expansions and contractions in flow geometry;
- to accurately describe variations in channel and overbank resistance;
- at bends in the stream to ensure that channel and overbank reach lengths are correctly defined; and
- beneath any existing bridges in place.

Photographs of each cross section should be taken. Each should be well labeled to identify it. The photos should be taken at a time when the vegetation and channel are not obscured by snow or ice.

Profiles (HYD-1, Section 7)

The profiles are needed to determine the energy gradient of the channel and to aid in establishing the invert elevations of the required structures. The required profiles are: (1) a profile of the thalweg (a line describing the lowest point in the channel) and (2) a profile of the water surface. The thalweg profile of such rivers as the Missouri, Yellowstone, and Clarks Fork are very difficult and may be omitted if an adequate water surface profile is taken.

The profiles should extend 500 feet or two bridge lengths (whichever is longer) upstream and 1500 feet downstream from the proposed crossing. The profiles should be extended when necessary to incorporate ties to confluences with other streams, dams, splits in the channel, buildings, or any other features that could influence the proposed construction. Also show the locations of cross sections on the profile.

Plan (HYD-1, Section 8)

The plan section serves two purposes: (1) the hydraulic designer uses it to determine some of the hydraulic features of the crossing, such as the basin overtopping elevation, and (2) the Bridge Bureau uses it to locate new bridge ends when a bridge is required.

Section 8 need not be completed for projects that are photo mapped. For in-house projects, provide the survey so Section 8 can be completed by the Bridge Bureau. Refer to the previous note under the heading "Cross Sections (HYD-1, Section 6)" above for bridge design requirements.

The plan should show the detailed topography and contours of the immediate crossing area. The contours provide the most important information in this section. The contour interval should be chosen carefully so that good elevation detail is shown and so the plan does not become cluttered. The horizontal scale should be chosen as large as possible but small enough so that all of the topography will still fill the space provided.

Irrigation Surveys

Anytime a proposed construction project will cross or in any way affect an irrigation ditch, an irrigation survey should be made. Form HYD-1 should be filled out completely with the exception of Section 1, Watershed Data. The Watershed Data does not apply to irrigation crossings.

Section 2, Existing Structure, and Section 3, Erosion and Geology Data should be completed in the same manner as for a natural waterway.

Much of the information requested in Section 4 will require some research but it is extremely important and must be completely filled in. Because the ditch company must always be contacted for approval of plans, the name of the ditch and the name and address of the owner should be provided. Many times a government agency such as the U.S. Bureau of Reclamation, U.S. Bureau of Indian Affairs, or the Montana Department Conservation and Water Resources has control and jurisdiction over an irrigation district. If this is the case, the name of the agency concerned should also be provided.

The hydraulic data requested in Section 4, such as capacity, slope, depth, and ditch dimensions, should be that provided by the ditch company and not the surveyed values. If the ditch carries flood water, this should be indicated and an explanation attached.

The location sketch should contain all of the information required for natural drainages plus a layout of the entire irrigation system within the scope of the sketch. All main canals, laterals and field ditches and their direction of flow should be shown. All hydraulic structures such as pipes, flumes, turnouts, drops, checks and headgates should be located. The invert elevations of these structures should be indicated. Note any washout areas. If the project is photo mapped, the location of the hydraulic structure may be shown on a copy of the photo map.

The cross sections taken for irrigation should be typical sections that will represent a section of the ditch. Any time any of the channel characteristics, such as shape, area, vegetation and channel materials, change another cross section should be taken. The location of each section and the reach of the ditch for which each section is typical should be indicated in Sections 5 and 8. Vegetation and channel bottom material should be accurately described so the channel roughness can be determined. Photographs of each typical section should be submitted.

A profile of the invert and a profile of the water surface should be provided for each ditch. Slopes as flat as 0.0002 foot per foot are not unusual for irrigation ditches so it may be necessary to extend the profiles at least 1,500 feet downstream and measure elevations to hundredths of a foot in order to establish the slope. The invert elevations of structures, such as turnouts, checks, etc., should be recorded. If a channel change is required, a profile should be run along the approximate channel change line.

The Plan (Section 8) should be completed in the same manner as for natural watersheds. However, the contours need not be drawn for irrigation crossings unless the crossing is so complex that it cannot be easily represented by a couple of cross sections. Section 8 is not required for projects that are photo mapped.

If the irrigation systems are complex and are to be involved in a revamping or a possible relocation of the irrigation, the irrigation ditches and facilities should be traced out far enough so that an adequate design can be made.

Urban Storm Drainage

The information required to design a storm drain is extensive and variable. This makes it difficult to give a complete and accurate description of the needed information. The intent here is to present a general idea of what is needed and why it is needed and let you use your judgment in conducting the storm drainage survey.

Contributing Area

Determining the area that contributes to the storm drain runoff is the most difficult part of the storm drain survey. Most storm drains pick up water that runs onto the highway from side streets.

A detailed description of side drainages should be given so drainage areas and runoff coefficients can be determined. The description should include such information as drainage limits, direction of flow on each street, street widths, type of surfacing, land use (residential, commercial, etc.), location at which it intercepts the highway, and location and size of any large paved areas such as parking lots. If there is an existing storm drain in place in any of the contributing areas, the location of all inlets, manholes, and the size of pipe should be given.

Most needed information can easily be given on a map of the area that is drawn to scale and is large enough to show all necessary details. Any other information that could be pertinent to the design of the storm drain system should be included.

Outfalls

It is always necessary to discharge the storm drain into a natural drainage at some point or points along the system. It is the responsibility of the survey personnel to search out all possible outfall lines and provide a survey of each line. Some storm drains do not have an obvious outfall line, and a very detailed search is required. If no outfall line can be found, the Hydraulics Unit should be notified. The outfall survey should include a traverse tied to the centerline survey, property ties, all pertinent topography, and a profile.

Settling Basin

Anytime a storm drain is discharged into a perennial stream that contains fish life or is used extensively for drinking water, a settling basin is required near the stream.

The settling pond should be located on the outfall line downstream of the point at which all of the water has been collected. The shape of the basin can be varied to fit the area available. A minimum of one acre of land is required and it must be on or immediately adjacent to the outfall line.

Utilities

All buried utilities that could affect the installation of the storm drain must be accurately located. The size, depth, and location of each utility must be recorded. The depth given should be referenced to some datum. The invert elevations of all manholes and connections on gravity systems such as sanitary sewers and storm drains should be given if possible. Contact the utility companies and city to get most of this information. If for some reason they cannot provide the needed information, some field work may be necessary.

Water Supply

The need for water for irrigation and domestic purposes is becoming greater as more landscaping projects and rest areas are built. The primary sources of water for these projects are wells and springs. Good information is needed to efficiently develop these sources.

Water Wells

The well is the main source of water for the majority of landscaping and rest area projects, and weigh stations. A great deal of information is required to design the pumping and distribution systems and to efficiently develop the well. The required information is requested on Form HYD-2, shown in Figure 10-9 on Page 10-29. It is the responsibility of the Core Drill Section to see that the form is properly filled out and submitted to the Preconstruction Bureau.

Well Information. The well information requested on Form HYD-2 will provide all the necessary information about the well. The size and type of casing, size and location of perforations, and size and location of screens, if they are used, should be indicated on the form. Many times the casing and screens are pulled after test pumping and the contractor is required to redrill the well under the construction contract. If the casing and screens were pulled, this should be indicated on Form HYD-2. The elevation at the top of the well should be the ground elevation at the well and should serve as the datum for all measurements to the water level and bottom of the well.

Water Information

The water information that is requested on From HYD-2 is extremely important and should be recorded accurately and completely. The value of a pumping test can be increased greatly with a little additional effort, time and expense. Never be afraid to make too many measurements or observations. The depth of static water level should be measured before the test pumping starts and should be measured from the top of well datum elevation. The type and size of the test pump are used in analyzing the pumping test data.

The date on which the test pumping is done and the question about the amount of fluctuation in the water table are also important and deserve some time. If a pump test is run in May when the water table is high and the well is used in August when the water table has dropped considerably, problems could arise with the pumping system. Therefore, information about any fluctuation in the water table from year to year or season to season should be submitted. Local residents with nearby wells might be of some help in determining this information.

The pumping test should be conducted in accordance with good well testing procedures. The test should be run for a minimum of three (3) different production rates with the water pumped long enough at each rate to establish ultimate drawdown curves. The last rate should be near the maximum capacity of the well or 70 GPM. Some sprinkler systems require up to 70 GPM so the wells should be test pumped at these flows if possible. The time, pumping rate, and depth to water should be recorded continuously throughout the test. Water level recovery times and rates upon completion of pumping should also be recorded. The remarks might contain such information as appearance of water, temperature, etc. The length of the pump test varies greatly depending on the aquifer. A sample of the water should be taken near the end of the test for chemical analysis.

A copy of the well log required by the Water Resources Division of the Department of Natural Resources and Conservation and a copy of the results of the water quality tests should be attached to Form HYD-2.

Springs

Occasionally, springs will be developed as water supplies. If such a situation arises, the required information will be requested by the Hydraulics Unit on a case-by-case basis. However, certain information will always be required for the development of a spring. This information includes the elevation of the spring, an approximate flow rate, and the topography surrounding the spring. A water sample for chemical analysis should also be submitted to the Department of Health and Environmental Sciences. Photographs of the area are also quite helpful and should be submitted.

Waste Water Disposal

If waste water and sewage are created, such as in rest areas and weigh stations, some sort of disposal system must be constructed to dispose of them. The type of disposal system depends primarily on two considerations: (1) the distance to the water table from ground elevations and (2) the soil characteristics. A high water table eliminates the possible use of a drainfield because the Department of Health and Environmental Sciences requires the bottom of the drainfield to be at least 4.0 feet above the maximum ground water table. A highly impervious soil requires such a large drainfield that it becomes impractical.

The information required for the disposal system design includes a test for the ground water table elevation, percolation tests, and a contour map of the area.

At least one hole should be dug to determine the ground water table elevation. The hole should be excavated until the water table is reached or until it is seven feet deep and water is not encountered. It is felt that if the ground water table is over seven feet deep, it will not adversely affect a drainfield. The ground water table elevation should be measured when the water table is at its highest point during the year. This is normally in the spring.

Sometimes, it is necessary to monitor the ground water elevation for an extended period of time. This is done by placing a shallow well in the ground and periodically recording the water elevation. The well should be placed by digging or boring a minimum of a six-inch diameter hole and placing a four-inch perforated plastic pipe in it. The hole then should be backfilled with gravel and a cap placed on the top of the plastic pipe. It is the responsibility of the Hydraulics Unit to request the well and give the approximate placement location. The approximate depth and the frequency with which the water elevation should be recorded are provided with the request for the well.

Percolation tests determine the acceptability of the site and aid in the design of the subsurface disposal system. The length of time required for making percolation tests varies in different types of soil. The best method is to make test holes and keep them filled overnight with water.

A minimum of four percolation test holes should be made in the drainfield area, more if there is a variation in the soil texture throughout the area. The following procedure is suggested for making percolation tests:

1. Dig or bore the hole 4 to 12 inches in diameter, sides vertical, to a depth of at least 3 feet. Holes can be bored with a 4-inch diameter posthole auger.
2. Roughen or scratch the glazed bottom and sides of the hole to provide a natural surface. Remove all loose materials from the hole. Place about 2 inches of coarse sand or fine gravel in the hole to prevent the bottom from scouring.
3. Fill the hole with clear water to a minimum depth of 12 inches over the gravel. By refilling, if necessary, or by supplying a surplus reservoir of water (automatic siphon), keep water in the hole for at least 4 hours, and preferably overnight. In sandy soils containing no clay, the

above saturation procedure is not necessary and the test can be made after the water from one filling has seeped away.

4. Except in sandy soils, percolation rate measurements should be made on the day following the saturation process.
5. If water remains in the test hole after overnight saturation, adjust the water depth to 6 inches over the gravel. From a fixed reference point, measure the drop in water level over a 30-minute period.
6. If no water remains in the hole after overnight saturation, add clear water to a depth of about 6 inches over the gravel. From a fixed reference point, measure the height of the water surface at approximately 30-minute intervals over a 4-hour period, refilling the hole to a depth of 6 inches as necessary. The drop that occurs during the final 30-minute period is used to calculate the percolation rate.
7. In sandy soils, or other soils in which the first 6 inches of water seeps away in less than 30 minutes, after the overnight saturation period, the time interval between measurements can be taken as 10 minutes and the test run over a period of 1 hour. The drop that occurs in the final 10-minute period is used to calculate the percolation rate.

A contour map of the proposed drainfield area is necessary for the design of the drainfield. A contour interval no greater than 1 foot is required.

The unit in charge of selecting the rest area site will request percolation tests for determining the adequacy of the site for a waste disposal system. It is the responsibility of the Hydraulics Unit to request any additional data, such as percolation tests or ground water elevations, for the final waste disposal system design. The Hydraulics Unit will supply a sketch of the rest area that shows the approximate location where the water table should be checked, the number and approximate location of the percolation tests, and the approximate area (including comfort station) that should be contour mapped. Any additional information that could be pertinent to the design of a waste disposal system should also be sent to the Hydraulics Unit.

Small Earth Fill Dams

It is sometimes possible to use a highway fill as a small dam and back up water either for flood routing purposes or for use as a stock pond. This situation usually requires a crossing with a small drainage area (ten square miles or less) and a high fill. In order to safely design such a crossing, some special information is required in addition to a completed Form HYD-1. It is the responsibility of the Hydraulics designer to request the additional information if it is felt that the fill could possibly be used in this manner.

Provide a discussion of damage that could result if the fill washed out. The location and description of all buildings, crops, ditches, etc., that are downstream from the highway and could be damaged should be submitted.

It is necessary to determine the storage capacity of the reservoir that will build up behind the fill. In order to do this, a contour map of the area upstream is required. A contour interval of five feet is normally sufficient. The contours should go as high as the top of the fill.

The location and elevation of anything on the upstream side of the fill that could be flooded and damaged should be recorded. Some description of the land and vegetation that could be flooded should also be provided.

It is the responsibility of the Hydraulics Unit to request the Materials Bureau to supply a soils survey and their recommendations for the construction of the fill.

Roadside Erosion

Erosion in roadside ditches, median ditches, on cut and fill slopes, etc., is a problem that should be handled during the original design. However, because of the lack of information and the tremendous amount of work involved in checking every situation on every project, provisions for erosion control are rarely included in the original design. The best way to recognize potential erosion situations is by reviewing similar situations in the immediate vicinity.

It is your responsibility to recognize, note and comment on all potential erosion locations at the time the location survey is made. Take note of any erosion in existing roadside ditches, on cut and fill slopes, on hill sides, and in nearby gullies. If these locations show signs of erosion, the potential for erosion of the newly exposed slopes of the new highway is great. If a particular erosion control method or material has worked well in the past in the vicinity, recommendations concerning that particular method or material should be made.

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: _____ No. _____
Stream name: _____ Sta. _____
County: _____ Date: _____
Surveyed By: _____

FOR ORAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable
   See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHEO OATA

Estimated drainage area _____ Acres or Square miles
Area not contributing to runoff _____
Comment on land use or cover _____
_____
Floating debris: None ☐ , Light ☐ , Medium ☐ , Heavy ☐
Other ☐ , Quantity of Debris _____
Ice Light ☐ , Moderate ☐ , Severe ☐
Unusual Characteristics _____
_____
Elev. of water on data of survey _____
Elev. of low water _____ , normally dry ☐
Elev. of high water _____ , date occured _____
Cause Backwater from ice ☐ , Backwater from Construction ☐ ,
Cloudburst ☐ , Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property _____ if so what elev. will water be
[illegible] to reach _____
should crossing be designed for fish passage _____
_____

SECTION 2 EXISTING STRUCTURE

A. Culvert Size _____ , Type _____
Condition _____ , Length _____
B. Bridge: Type _____
No. of spans _____ , Length of each span _____ ,
_____ , _____ , _____
Clearance _____
Condition _____
C. Approximate distance above or below site _____
Highwater mark elev. _____
Historical adequacy _____
_____
Comments _____
_____
_____
_____
_____

SECTION 3 EROSION AND GEOLOGY OATA

Do banks or bed show scour? _____ , is channel stable ☐ ,
degrading ☐ , agrading ☐ , unknown ☐ is riprap or bank protection necessary? _____
Are the following material available locally: Riprap _____ ,
Type _____ , Filter Meterial No. 1 _____ ,
No. 2 _____
Is water or soil alkaline _____ , acidic _____
are sulphates present _____
Comments: _____
_____
_____

SECTION 4 IRRIGATION OATA

Name of Ditch _____
Owner _____
Address of ditch company _____
Ditch capacity _____ , Slope _____ , Water depth _____ , Bottom width _____ ,Side slopes _____ , Total depth _____
Does ditch carry flood water also? _____
Flow line elevations of existing structure, inlet _____ outlet _____

COMMENTS _____

_____
_____
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SECTION 5 LOCATION SKETCH

[illegible] will influence the proposed construction.
[illegible]: 1" =

SECTION 6 CR

Instructions: Note cross-sections
(3) Vegetation described and acc
In this case, a smaller horizontal s

(A) Provide typical section downst
(C) Provide section under existing
(E) Indicate location of each secti

[illegible] be clearly shown. (Contours are not necessary for irrigation)
[illegible] of water on date of survey. (F) Indicate location of cross-sections shown in Section 6.

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: _____ No. _____
Stream name: _____ Sta. _____
County: _____ Date: _____
Surveyed By: _____

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Estimated drainage area _____ Acres or Square miles
Area not contributing to runoff _____
Comment on land use or cover _____

Floating debris: None ☐ , Light ☐ , Medium ☐ , Heavy ☐
Other ☐ , Quantity of Debris _____
Ice Light ☐ , Moderate ☐ , Severe ☐
Unusual Characteristics _____

Elev. of water on date of survey _____
Elev. of low water _____ , normally dry ☐
Elev. of high water _____ , date occured _____
Cause Backwater from ice ☐ , Backwater from Construction ☐ , Cloudburst ☐ , Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property _____ if so what elev. will water be allowed to reach _____
should crossing be designed for fish passage _____

SECTION 2 EXISTING STRUCTURE

A. Culvert Size _____ , Type _____
Condition _____ , Length _____
B. Bridge: Type _____
No. of spans _____ , Length of each span _____ , _____ , _____ , _____
Clearance _____
Condition _____
C. Approximate distance above or below site _____
Highwater mark elev. _____
Historical adequacy _____

Comments _____

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? _____ , is channel stable ☐ , degrading ☐ , agrading ☐ , unknown ☐ is riprap or bank protection necessary? _____
Are the following material available locally: Riprap _____ , Type _____ , Filter Material No. 1 _____ , No. 2 _____
Is water or soil alkaline _____ , acidic _____
are sulphates present _____
Comments: _____

SECTION 4 IRRIGATION DATA

Name of Ditch _____
Owner _____
Address of ditch company _____
Ditch capacity _____ , Slope _____ , Water depth _____ , Bottom width _____ ,Side slopes _____ , Total depth _____
Does ditch carry floods water also? _____
Flow line elevations of existing structure, inlet _____ outlet _____

COMMENTS _____

SECTION 5 LOCATION SKETCH

SCALE: 1" = 500'

Instructions: Show centerline of survey, north arrow, general course of stream, existing structures, location of all channel cross-sections shown in Section 6, and all general topography.

SECTION 6 CROSS SECTIONS

Scale Horizontal: 1" = Scale Vertical: 1" =

Instructions: Note cross-sections should embody the following general characteristics, (1) Normal to channel, (2) Section extremities to extend well above the maximum possible flood, (3) Vegetation described and accurately located within 2', (4) Elevation differences of 6" or greater defined, (5) Use scale at 1" = 10' vertical and horizontal unless there is an extensive flood plain. In this case, a smaller horizontal scale may be used so as to define the flood and low water channel. The low water portion should also be plotted again using a larger scale.

(A) Provide typical section downstream from all proposed structures, (B) Provide cross-section at approximate construction limits upstream and downstream from all gravel crossings (C) Provide section under existing bridges to include substructure details, spill-slopes, channel and high water marks (D) Provide typical section of any irrigation ditches, etc. that will be affected by the construction. (E) Indicate location of each section in Section 5 and 8. (F) Attach photos of each section (G) When there is not enough room on this sheet plot additional cross-sections on a sheet of cross-section paper and attach it to this sheet.

SECTION 7 PROFILE

Instructions: (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft. up and downstream from the centerline. Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction. (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel. (C) Provide profiles for proposed channel change, dikes, etc. (D) Indicate scales. HORIZONTAL: 1" = VERTICAL: 1" =

SECTION 8 PLAN

Instructions: (A) Use scale 1" = 10', 1" = 20', or 1" = 50' depending on extent of field data. (B) Indicate stationed centerline of survey. (C) Draw contours with an interval as small as can be clearly shown. (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding. If overtopping of finish grade only, check here ☐ (E) Stream meander and edge of water on date of survey. (F) Indicate location of cross-sections shown in Section 6. (G) Indicate existing roads and structures. (H) Indicate other features that may influence design.

Form HYD. 1 Figure 10-2 Example No. 1 Intermediate Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Big Timber Reedpoint No. RF-127 (7)
Stream name: Upper Dear Creek Sta. 343+86.5
County: Sweetgrass Date: 4-3-72
Surveyed By: R. W. Saltzman

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff None
Comment on land use or cover 1/3 Mountainous (60* Forest Cover), 1/2 Range land, 1/6 River bottom
Floating debris: None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐. Quantity of Debris
Ice Light ☒, Moderate ☐, Severe ☐
Unusual Characteristics None
Elev. of water on data of survey 3964.0
Elev. of low water 3963.5, normally dry ☐
Elev. of high water 3972.0, date occured June 1967
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☒
Will ponding of water upstream cause damage to buildings or other property Yes if so what elev. will water be allowed to reach 3973.0
should crossing be designed for fish passage Yes, The elevations are measured at the upstream edge of the existing bridge.

SECTION 2 EXISTING STRUCTURE

A. Culvert Size , Type
Condition , Length
B. Bridge: Type Steel and Concrete
No. of spans 1, Length of each span 38'
Clearance 8.5'
Condition Bridge-fair, Abutments-poor
C. Approximate distance above or below site on centerline
Highwater mark elev. 3967.0
Historical adequacy Washed out in 1967, see comment below.
Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? Yes, is channel stable ☒, degrading ☐, agrading ☐, unknown ☐ is riprap or bank protection necessary? Yes
Are the following material available locally Riprap Yes,
Type A or B, Filter Material No. 1 Yes, No. 2 Yes
Is water or soil alkaline No, acidic No
are sulphates present No
Comments:

SECTION 4 IRRIGATION DATA

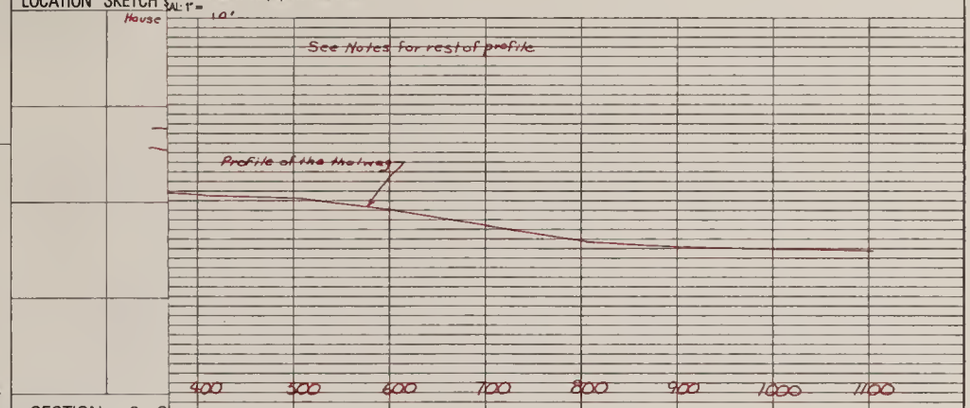
Name of Ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water depth , Bottom width , Side slopes , Total depth
Does ditch carry flood water also?
Flow line elevations of existing structure, inlet outlet

COMMENTS

Present Structure has been adequate to handle the flow during normal runoff. A 5 1/8" rainfall in 48 hours, in June 1967, caused a flash flood that undermined the abutments of this bridge over US Highway #10. Debris blocking the inlet end of this structure was a partial cause of the failure. In the event such as in June 1967, the present highway bridge could wash out again due to the heavy debris and down timber in the stream bed.

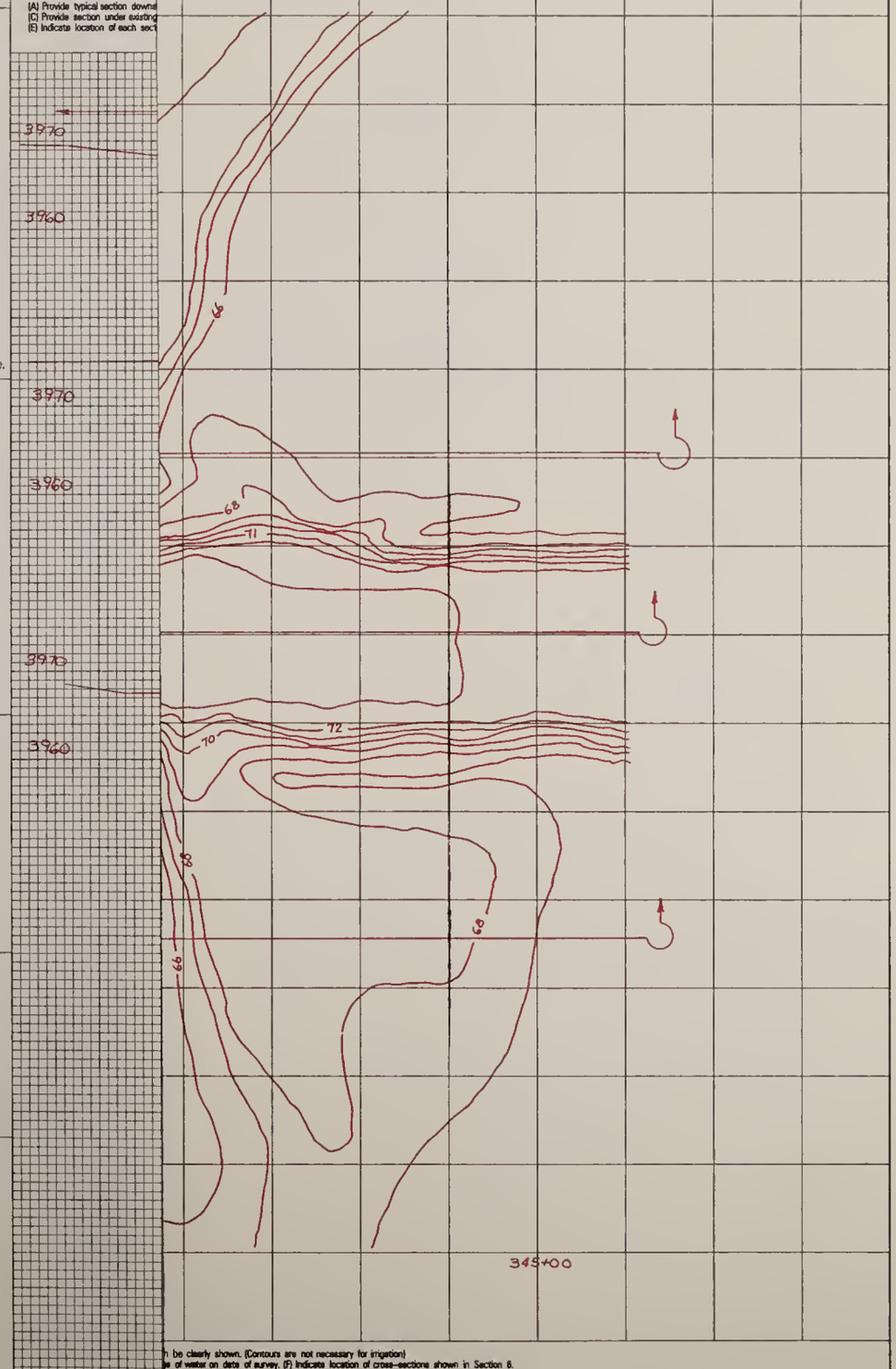
SECTION 5 LOCATION SKETCH

that will influence the proposed construction.
SCALE: 1" = 10'



SECTION 6 C

Instructions. Note cross-sections
(3) Vegetation described and ac
In this case, a smaller horizontal
(A) Provide typical section downs
(C) Provide section under existing
(E) Indicate location of each sec



n be clearly shown. (Contours are not necessary for irrigation)
e of water on date of survey. (F) Indicate location of cross-sections shown in Section 8.

Form HYD. 1 Figure 10-2 Example No. 1 Intermediate Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Big Timber Reedpoint No. RF-127 (7)
Stream name: Upper Deer Creek Sta. 343+86.5
County: Sweetgrass Date: 4-3-72
Surveyed By: R. W. Soltzman

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff None
Comment on land use or cover 1/3 Mountainous (60' Forest Cover), 1/3 Range land, 1/6 River bottom
Floating debris: None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☑, Moderate ☐, Severe ☐
Unusual Characteristics None

Elev. of water on data of survey 3964.0
Elev. of low water 3963.5, normally dry ☐
Elev. of high water 3972.0, date occurred June 1967
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☑
Will ponding of water upstream cause damage to buildings or other property Yes if so what elev. will water be allowed to reach 3973.0
should crossing be designed for fish passage Yes, The elevations are measured at the upstream edge of the existing bridge.

SECTION 2 EXISTING STRUCTURE

A. Culvert Size , Type
Condition , Length
B. Bridge: Type Steel and Concrete
No. of spans 1, Length of each span 38',
, ,
Clearance 8.5'
Condition Bridge-fair, Abutments-poor
C. Approximate distance above or below site on centerline
Highwater mark elev. 3967.0
Historical adequacy Washed out in 1967, see comment below.
Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? Yes, is channel stable ☑, degrading ☐, agrading ☐, unknown ☐ is riprap or bank protection necessary? Yes
Are the following material available locally: Riprap Yes, Type A or B, Filter Material No. 1 Yes, No. 2 Yes
Is water or soil alkaline No, acidic No
are sulphates present No
Comments:

SECTION 4 IRRIGATION DATA

Name of Ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water depth , Bottom width , Side slopes , Total depth
Does ditch carry flood water also?
Flow line elevations of existing structure, inlet outlet

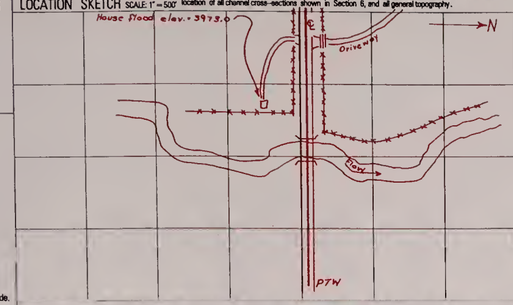
COMMENTS

Present Structure has been adequate to handle the flow during normal runoff. A 5⅛" rainfall in 48 hours, in June 1967, caused a flash flood that undermined the abutments of this bridge over US Highway #10. Debris blocking the inlet end of this structure was a partial cause of the failure. In the event such as in June 1967, the present highway bridge could wash out again due to the heavy debris and down timber in the stream bed.

SECTION 5 LOCATION SKETCH

SCALE: 1" = 500'

Instructions: Show centerline of survey, north arrow, general course of stream, existing structures, location of all channel cross-sections shown in Section 6, and all general topography.

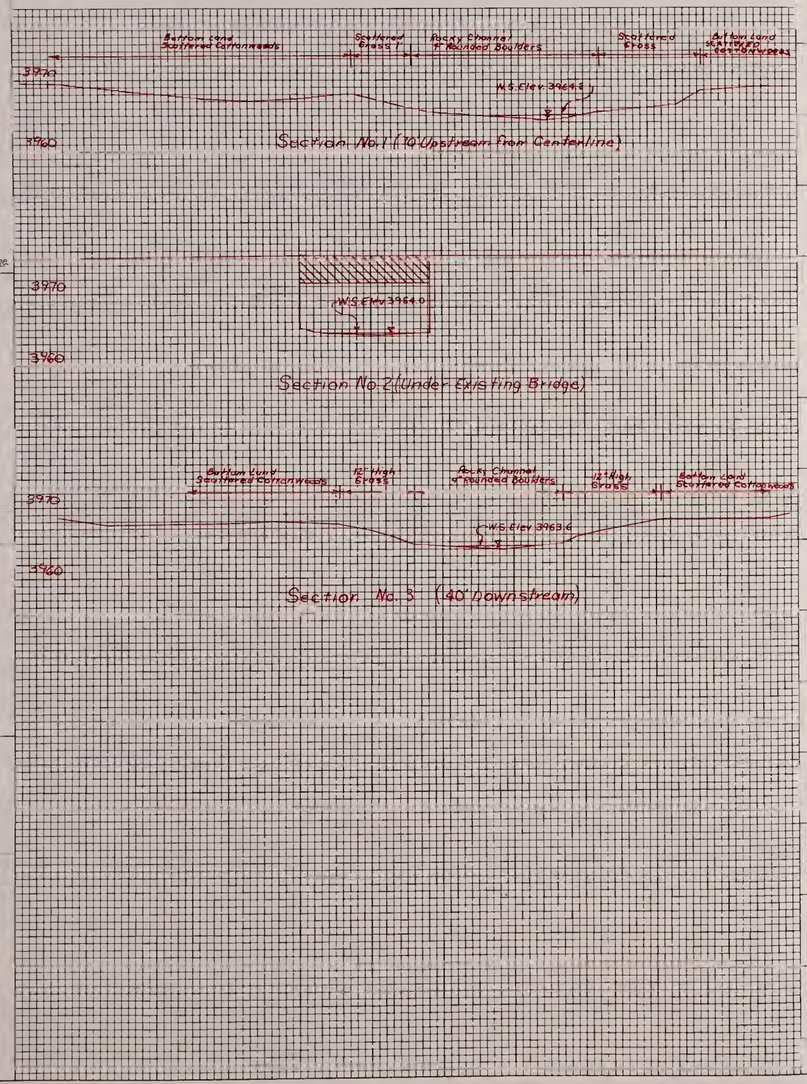


SECTION 6 CROSS SECTIONS

Scale Horizontal: 1" = 20' Scale Vertical: 1" = 10'

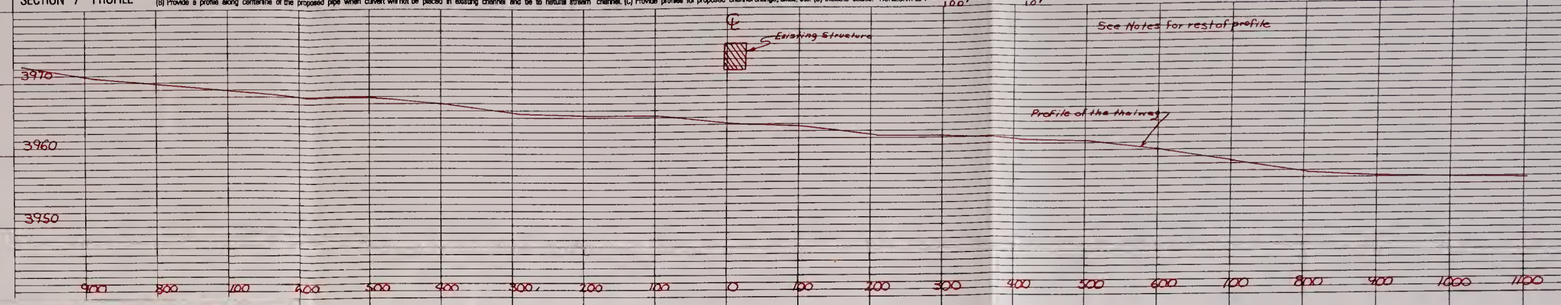
Instructions: Note cross-sections should embody the following general characteristics, (1) Normal to channel, (2) Section extremities to extend well above the maximum possible flood, (3) Vegetation described and accurately located within 2', (4) Elevation differences of 6" or greater defined, (5) Use scale at 1" = 10' vertical and horizontal unless there is an extensive flood plain in this case, a smaller horizontal scale may be used so as to define the flood and low water channel. The low water portion should also be plotted again using a larger scale.

(A) Provide typical section downstream from all proposed structures. (B) Provide cross-section at appropriate construction limits upstream and downstream from all proposed structures. (C) Provide section under existing bridges to include substructure details, spill-slopes, channel and high water marks (D) Provide typical section of any irrigation ditches, etc. that will be effected by the construction. (E) Indicate location of each section in Section 5 and 8. (F) Attach photos of each section (G) When there is not enough room on this sheet plot additional cross-sections on a sheet of cross-section paper and attach it to this sheet.



SECTION 7 PROFILE

Instructions: (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft. up and downstream from the centerline. Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction. (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel. (C) Provide profiles for proposed channel change, dikes, etc. (D) Indicate scales. HORIZONTAL: 1" = 100', VERTICAL: 1" = 10'



SECTION 8 PLAN

Instructions: (A) Use scale 1" = 10', 1" = 20', or 1" = 50' depending on extent of field data. (B) Indicate stationed centerline of survey. (C) Draw contours with an interval as small as can be clearly shown. (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding. If overtopping of finish grade only, check here ☐. (E) Stream meander and edge of water on date of survey. (F) Indicate location of cross-sections shown in Section 8. (G) Indicate existing roads and structures. (H) Indicate other features that may influence design.

Form HYD. 1 Figure 10-3 Example No. 2 Large Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: St. Regis E&W No. I-90-1(13)127
Stream name: Clark Fork River Sta. 658+00
County: Mineral Date: 7-12-68
Surveyed By: T. D. &H. Inc.

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff Negligible
Comment on land use or cover Mountainous

Floating debris: None ☐, Light ☒, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☐, Moderate ☐, Severe ☐
Unusual Characteristics None

Elev. of water on data of survey 2609.5
Elev. of low water 2608.7, normally dry ☐
Elev. of high water 2620.1, date occured 5-4-1948
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☒
Will ponding of water upstream cause damage to buildings or other property No if so what elev will water be allowed to reach
should crossing be designed for fish passage Yes

SECTION 2 EXISTING STRUCTURE

A. Culvert Size , Type
Condition , Length
B. Bridge: Type Concrete and Truss Girders
No. of spans ?, Length of each span ,
20', 42', 65', 57', 175', 225', 175'
Clearance 35.6'
Condition Good
C. Approximate distance above or below site 350' Below site
Highwater mark elev. 2610.9
Historical adequacy Very Adequate

Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No, is channel stable ☒, degrading ☐, agrading ☐, unknown ☐ is riprap or bank protection necessary? No
Are the following material available locally: Riprap Yes,
Type B, Filter Material No. 1 Yes,
No. 2 Yes
Is water or soil alkaline No, acidic No
are sulphates present No
Comments:

SECTION 4 IRRIGATION DATA

Name of Ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water depth , Bottom width , Side slopes , Total depth
Does ditch carry flood water also?
Flow line elevations of existing structure, inlet outlet

COMMENTS

It was felt that because of the uniformity of the channel one cross-section adequately described this crossing. Neither the PTW or the railroad present any constriction.

SECTION 5 LOCATION SKETCH

that will influence the proposed construction.
CAL: 1" = 1'

Notes for Extension of Profile

Surface on Date of Survey

Existing Railroad Structure

400 500 600 700 800 900 1000 1100

2660 2650 2640 2630 2620 2610 2600 2670

660+00

660+00

Hay, Brush

Surface on Date of Survey

P4 P5

n be clearly shown. (Contours are not necessary for irrigation)
ge of water on date of survey. (F) Indicate location of cross-sections shown in Section 8.

SECTION 6 C

Instructions: Note cross-sections
(3) Vegetation described and sc
In this case, a smaller horizontal
(A) Provide typical section down
(C) Provide section under existin
(E) Indicate location of each sec

Form HYD. 1 Figure 10-3 Example No. 2 Large Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: St. Regis E&W No. 1-90-1(113)27
Stream name: Clark Fork River Sta. 658+00
County: Mineral Date: 7-12-68
Surveyed By: T. D. & H. Inc.

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff Negligible
Comment on land use or cover Mountainous

Floating debris. None ☐, Light ☑, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☐, Moderate ☐, Severe ☐
Unusual Characteristics None

Elev. of water on date of survey 2609.5
Elev. of low water 2608.7, normally dry ☐
Elev. of high water 2620.1, date occured 5-4-1948
Cause Backwater from ice ☐, Backwater from Construction ☐,
Cloudburst ☐, Spring runoff ☑
Will ponding of water upstream cause damage to buildings or other property No if so what elev. will water be allowed to reach
should crossing be designed for fish passage Yes

SECTION 2 EXISTING STRUCTURE

A. Culvert Size , Type
Condition , Length
B. Bridge: Type Concrete and Truss Girders
No. of spans ?, Length of each span 20', 42', 65', 57', 175', 225', 175'
Clearance 35.6'
Condition Good
C. Approximate distance above or below site 350' Below site
Highwater mark elev. 2610.9
Historical adequacy Very Adequate
Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No, is channel stable ☑, degrading ☐, agrading ☐, unknown ☐ is riprap or bank protection necessary? No
Are the following material available locally: Riprap Yes,
Type B, Filter Material No. 1 Yes,
No. 2 Yes
Is water or soil alkaline No, acidic No
are sulphates present No
Comments:

SECTION 4 IRRIGATION DATA

Name of Ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water depth , Bottom width , Side slopes , Total depth
Does ditch carry flood water also?
Flow line elevations of existing structure, inlet outlet

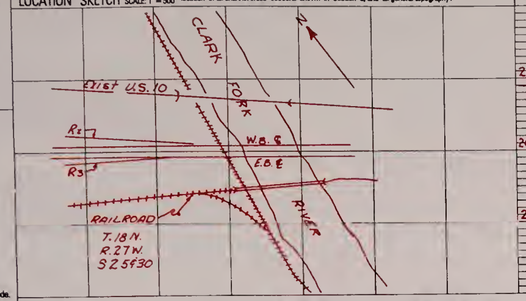
COMMENTS

It was felt that because of the uniformity of the channel one cross section adequately described this crossing. Neither the PTW or the railroad present any constriction.

SECTION 5 LOCATION SKETCH

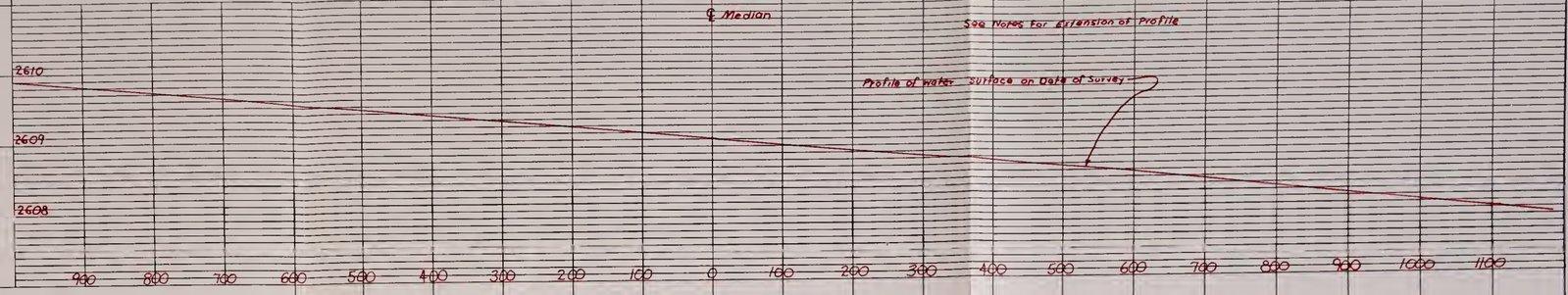
SCALE: 1" = 500'

Instructions: Show centerline of survey, north arrow, general course of stream, existing structures, location of all channel cross-sections shown in Section 6, and all general topography.



SECTION 7 PROFILE

Instructions: (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft. up and downstream from the centerline. Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction. (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel. (C) Provide profiles for proposed channel change, dikes, etc. (D) Indicate scales. HORIZONTAL: 1" = 100' VERTICAL: 1" = 1'

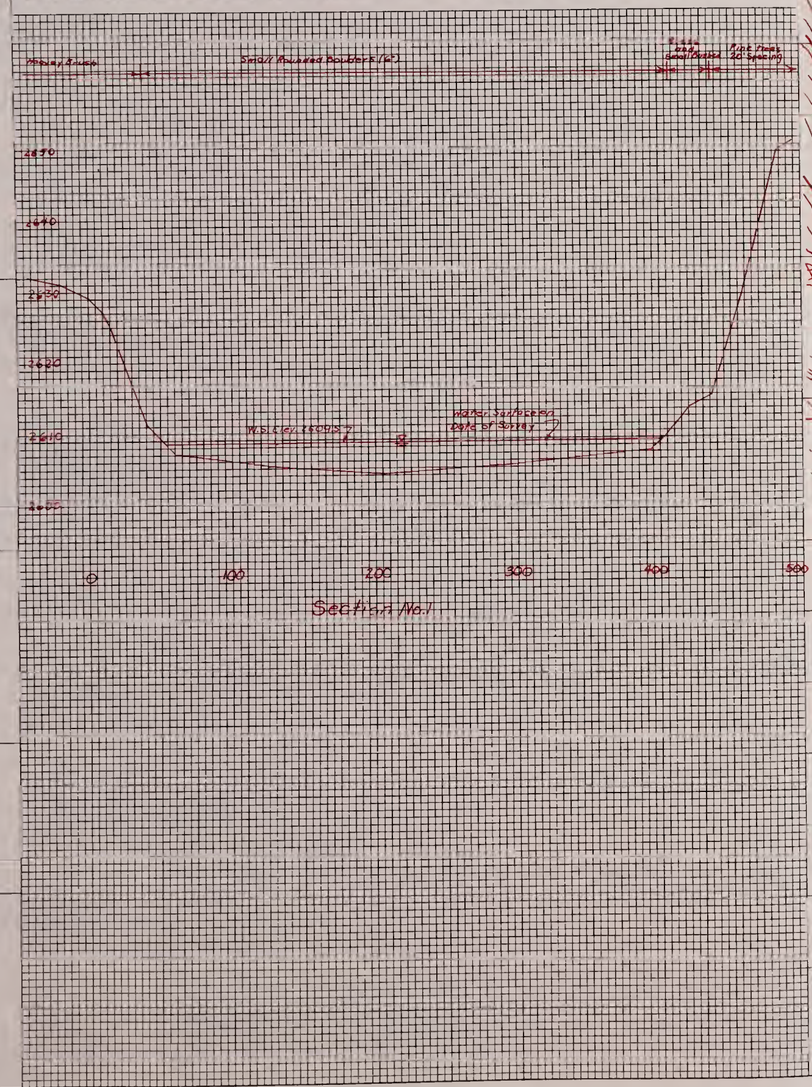


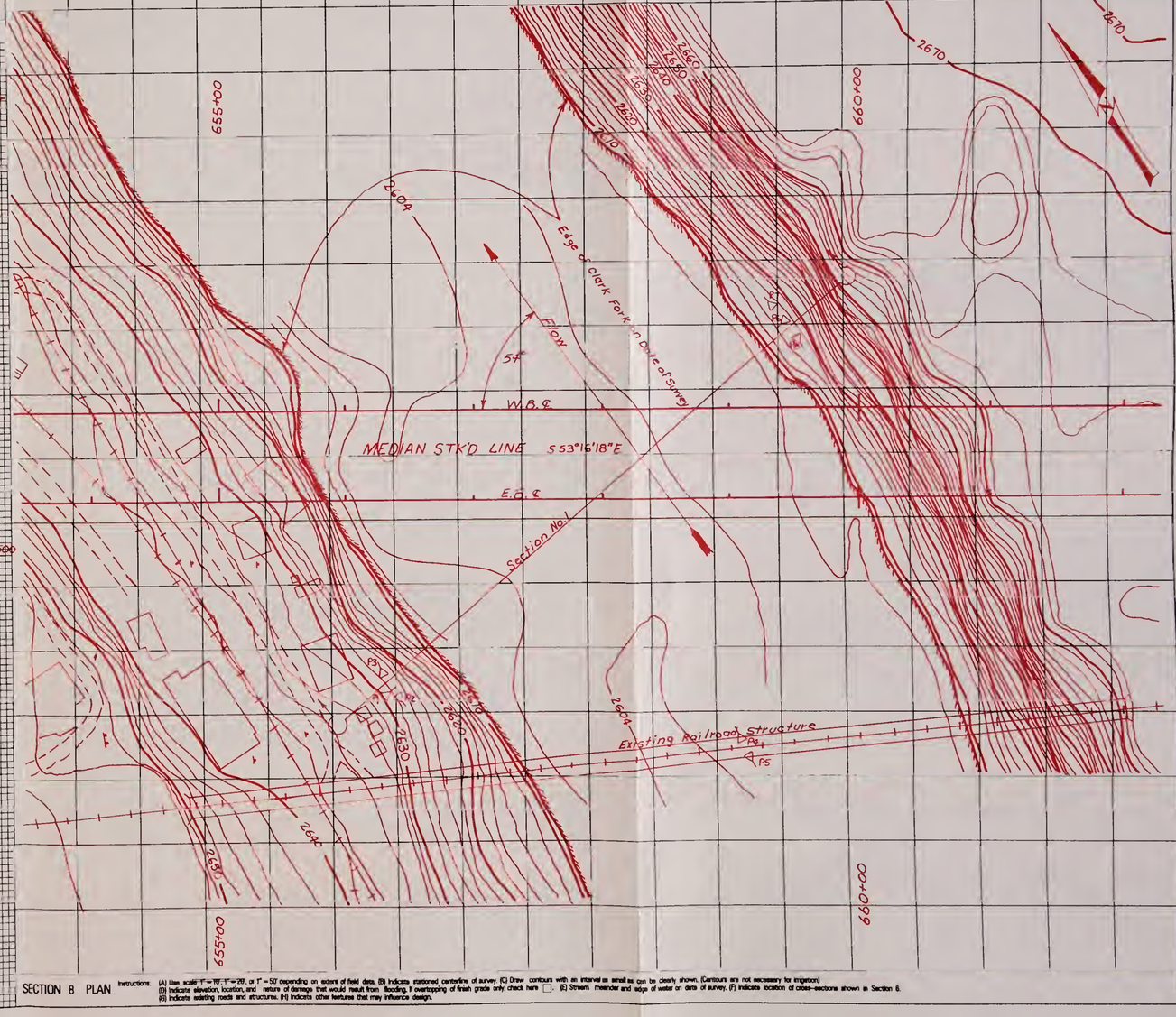
SECTION 6 CROSS SECTIONS

Scale Horizontal: 1" = 50' Scale Vertical: 1" = 10'

Instructions: Note cross-sections should embody the following general characteristics, (1) Normal to channel, (2) Section extremities to extend well above the maximum possible flood, (3) Vegetation described and accurately located within 2', (4) Elevation differences of 6" or greater defined, (5) Use scale at 1" = 10' vertical and horizontal unless there is an extensive flood plain. In this case, a smaller horizontal scale may be used so as to define the flood and low water channel. The low water portion should also be plotted again using a larger scale.

(A) Provide typical section downstream from all proposed structures, (B) Provide cross-section at appropriate construction limits upstream and downstream from all proposed crossings. (C) Provide section under existing bridges at include substructure details, spill slopes, channel and high water profile (D) Provide typical section of any irrigation ditches, etc. that will be affected by the construction. (E) Indicate location of each section in Section 5 and 8. (F) Attach photos of each section (G) When there is not enough room on this sheet plot additional cross-sections on a sheet of cross-section paper and attach it to this sheet.





SECTION 8 PLAN

Instructions: (A) Use scale 1" = 10' - 1" = 20', or 1" = 50' depending on extent of field data. (B) Indicate stationed centerline of survey. (C) Draw contours with an interval as small as can be clearly shown. (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding. If overtopping of finish grade only, check here ☐. (E) Stream meander and edge of water on date of survey. (F) Indicate location of cross-sections shown in Section 6. (G) Indicate existing roads and structures. (H) Indicate other features that may influence design.

Form HYD. 1 Figure 10-4 Example No. 3 Large Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Biddle-East No. S-460(3)
Stream name: Little Powder River Sta. 21+50
County: Powder River Date: 1-29-70
Surveyed By: C. W. Taylor

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff _____
Comment on land use or cover None

Floating debris: None ☐, Light ☒, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris _____
Ice Light ☐, Moderate ☒, Severe ☐
Unusual Characteristics None

Elev. of water on data of survey 3250.9
Elev. of low water 3249.8, normally dry ☐
Elev. of high water 3256.9, date occured ?
Cause Backwater from ice ☐, Backwater from Construction ☒,
Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property Yes if so what elev. will water be allowed to reach 3261.5
should crossing be designed for fish passage No

SECTION 2 EXISTING STRUCTURE

A. Culvert Size _____, Type _____
Condition _____, Length _____
B. Bridge: Type Steel Truss
No. of spans 1, Length of each span 107',
Clearance 22.5'
Condition Poor
C. Approximate distance above or below site 100' Upstream
Highwater mark elev. 3257.9
Historical adequacy This crossing has always been adequate.
Comments _____

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No, is channel stable ☒, degrading ☐, agrading ☐, unknown ☐ is riprap or bank protection necessary? Yes
Are the following material available locally: Riprap Yes,
Type A, Filter Material No. 1 No,
No. 2 No
Is water or soil alkaline Yes, acidic No
are sulphates present No
Comments: _____

SECTION 4 IRRIGATION DATA

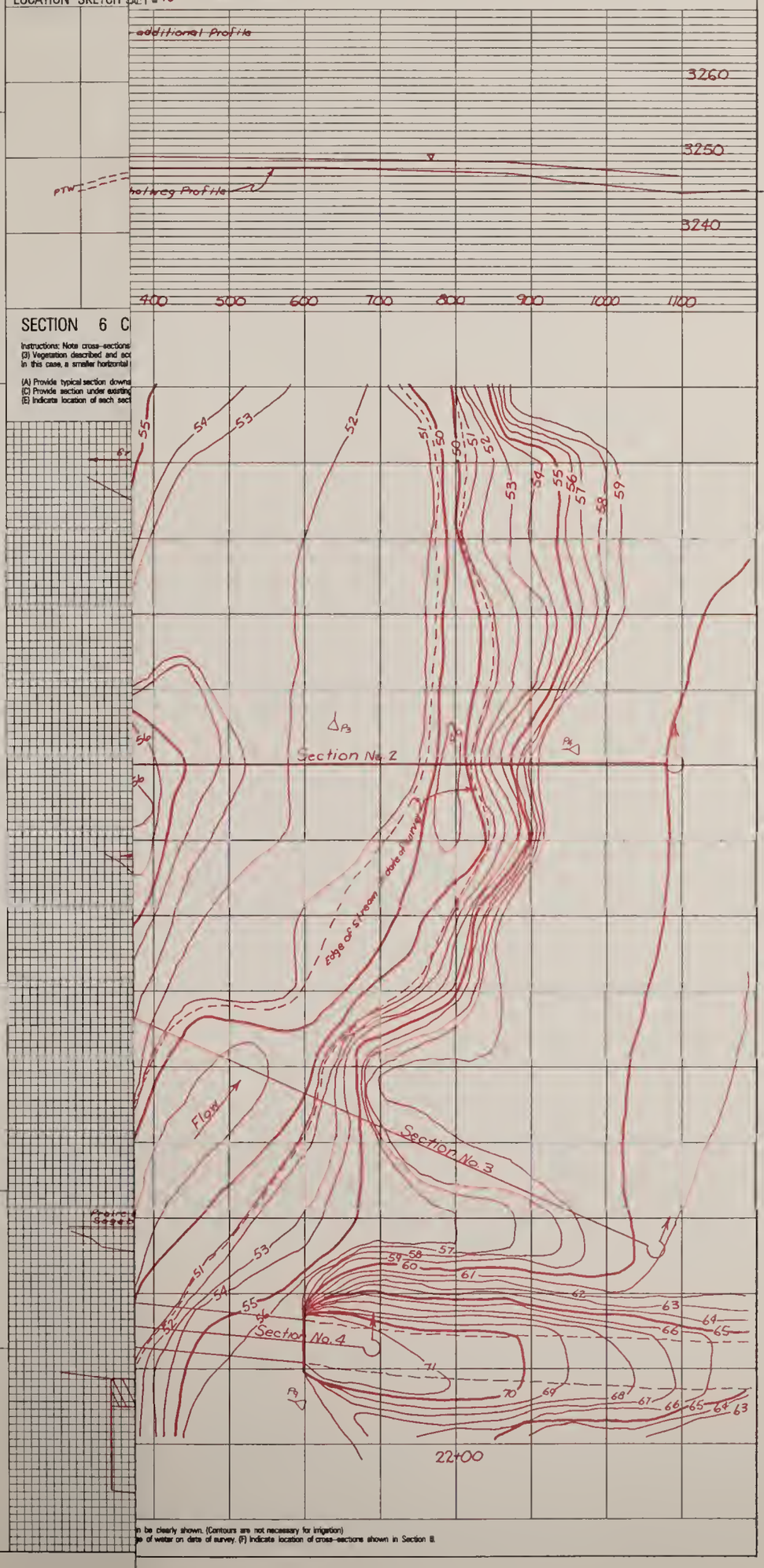
Name of Ditch _____
Owner _____
Address of ditch company _____
Ditch capacity _____, Slope _____, Water depth _____, Bottom width _____, Side slopes _____, Total depth _____
Does ditch carry flood water also? _____
Flow line elevations of existing structure, inlet _____ outlet _____

COMMENTS

This river dried up completely in August, 1967.

SECTION 5 LOCATION SKETCH

that will influence the proposed construction.
SCALE: 1" = 10'



SECTION 6 C

Instructions: Note cross-sections
(3) Vegetation described and sca
In this case, a smaller horizontal
(A) Provide typical section downs
(C) Provide section under existing
(E) Indicate location of each sect

n be clearly shown. (Contours are not necessary for irrigation)
e of water on date of survey. (F) Indicate location of cross-sections shown in Section 8.

Form HYD. 1 Figure 10-4 Example No. 3 Large Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Biddle East No. S-460(13)
Stream name: Little Powder River Sta. 21+50
County: Powder River Date: 1-29-70
Surveyed By: C.W. Taylor

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable. See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff _____
Comment on land use or cover None

Floating debris: None ☐, Light ☒, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris _____
Ice Light ☐, Moderate ☒, Severe ☐
Unusual Characteristics None

Elev. of water on data of survey 3250.9
Elev. of low water 3249.8, normally dry ☐
Elev. of high water 3256.9, date occured ?
Cause Backwater from ice ☐, Backwater from Construction ☒, Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property Yes if so what elev. will water be allowed to reach 3261.5
should crossing be designed for fish passage No

SECTION 2 EXISTING STRUCTURE

A. Culvert Size _____, Type _____
Condition _____, Length _____
B. Bridge: Type Steel Truss
No. of spans 1, Length of each span 107'
Clearance 22.5'
Condition Poor
C. Approximate distance above or below site 100' Upstream
Highwater mark elev. 3257.9
Historical adequacy This crossing has always been adequate.
Comments _____

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No, is channel stable ☒, degrading ☐, agrading ☐, unknown ☐ is riprap or bank protection necessary? Yes
Are the following material available locally: Riprap Yes, Type A, Filter Material No. 1 No, No. 2 No
Is water or soil alkaline Yes, acidic No
are sulphates present No
Comments: _____

SECTION 4 IRRIGATION DATA

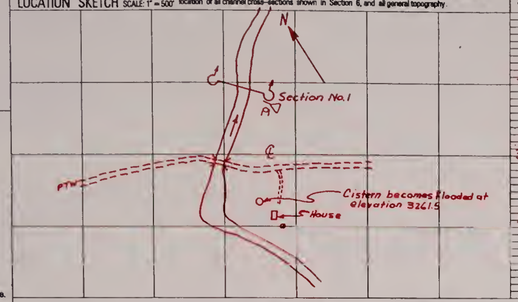
Name of Ditch _____
Owner _____
Address of ditch company _____
Ditch capacity _____, Slope _____, Water depth _____, Bottom width _____, Side slopes _____, Total depth _____
Does ditch carry flood water also? _____
Flow line elevations of existing structure, inlet _____ outlet _____

COMMENTS

This river dried up completely in August, 1967.

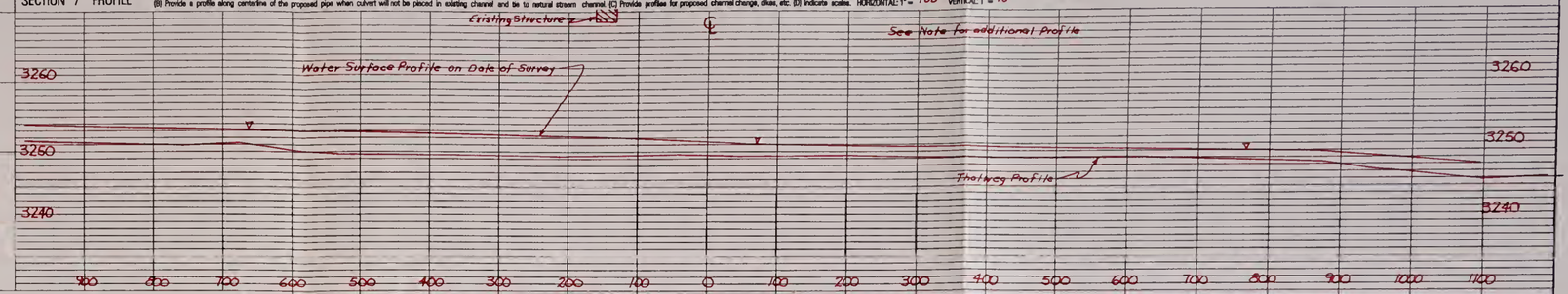
SECTION 5 LOCATION SKETCH SCALE: 1" = 500'

Instructions: Show centerline of survey, north arrow, general course of stream, existing structures, location of all channel cross-sections shown in Section 6, and all general topography.



SECTION 7 PROFILE

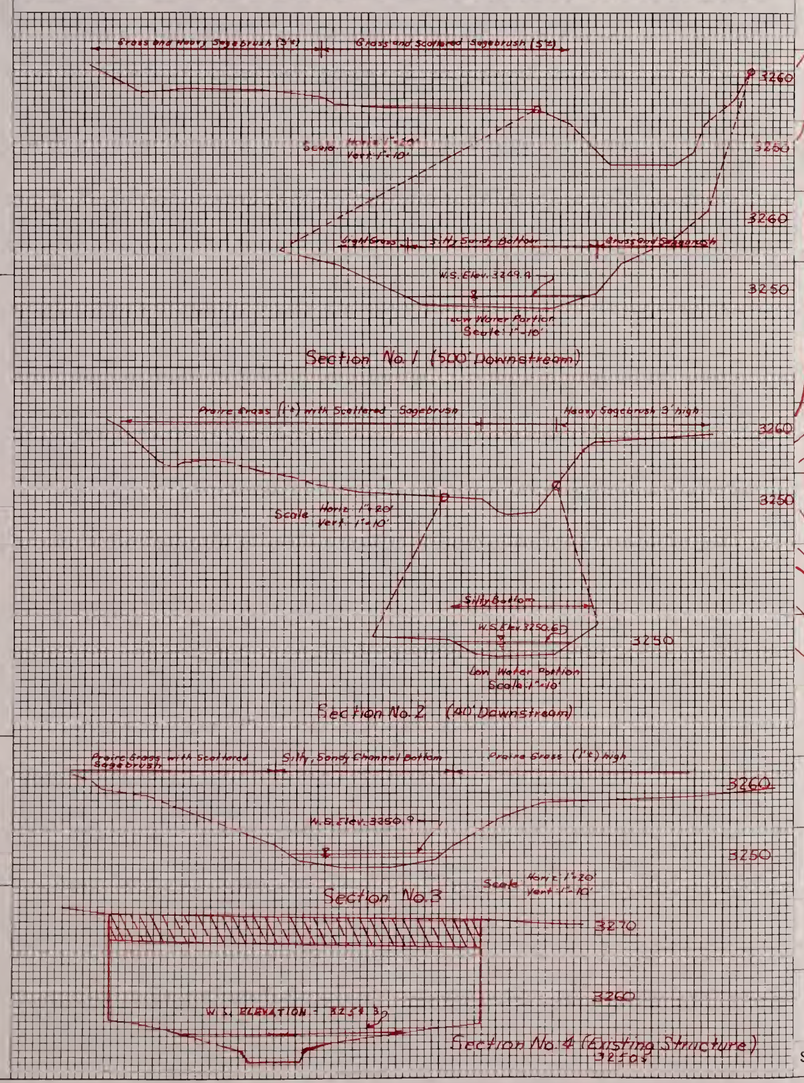
Instructions: (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft. up and downstream from the centerline. Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction. (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and be to natural stream channel. (C) Provide profiles for proposed channel change, dikes, etc. (D) Indicate scales. HORIZONTAL: 1" = 100 VERTICAL: 1" = 10

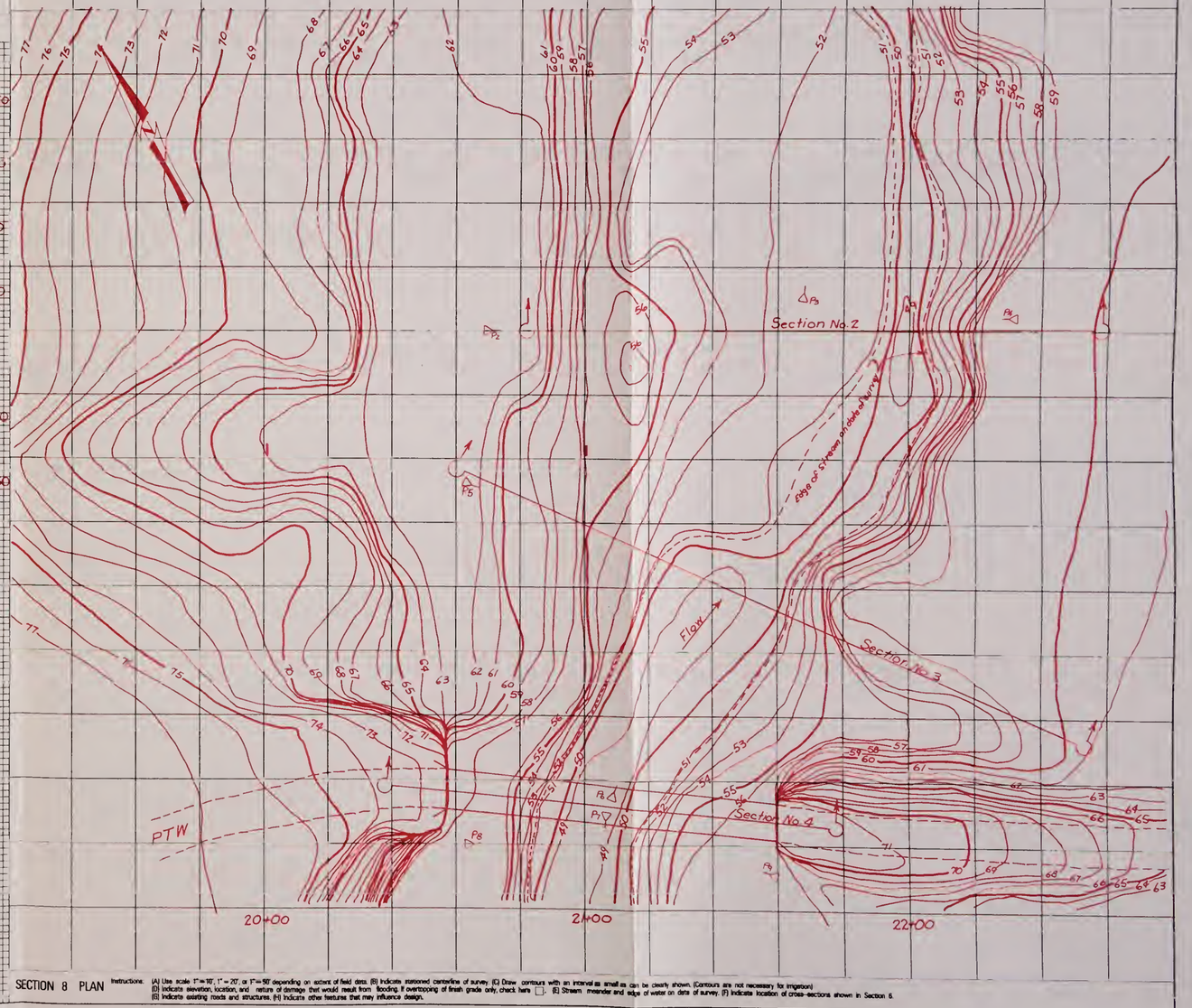

Existing Structure
See Note for additional Profile
Water Surface Profile on Date of Survey
Thalweg Profile
3260
3250
3240
900 800 700 600 500 400 300 200 100 0 100 200 300 400 500 600 700 800 900 1000 1100

SECTION 6 CROSS SECTIONS Scale Horizontal: 1" = Scale Vertical: 1" =

Instructions: Note cross-sections should embody the following general characteristics, (1) Normal to channel, (2) Section extremities to extend well above the maximum possible flood, (3) Vegetation described and accurately located within 2', (4) Elevation differences of 6" or greater defined, (5) Use scale at 1" = 10' vertical and horizontal unless there is an extensive flood plain. In this case, a smaller horizontal scale may be used so as to define the flood and low water channel. The low water portion should also be plotted again using a larger scale.

(A) Provide typical section downstream from all proposed structures, (B) Provide cross-section at each proposed construction limits upstream and downstream from all proposed change. (C) Provide section under existing bridges to include substructure details, pier shapes, channel and high water marks (D) Provide typical section of any irrigation ditches, etc. this will be affected by the construction. (E) Indicate location of each section in Section 5 and 8. (F) Attach photos of each section (G) When there is not enough room on this sheet plot additional cross-sections on a sheet of cross-section paper and attach it to this sheet.





SECTION 8 PLAN

Instructions: (A) Use scale 1"=10', 1"=20', or 1"=50' depending on extent of field data. (B) Indicate stationed centerline of survey. (C) Draw contours with an interval as small as can be clearly shown. (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding. If overtopping of finish grade only, check here ☐. (E) Stream meander and edge of water on date of survey. (F) Indicate location of cross-sections shown in Section 6. (G) Indicate existing roads and structures. (H) Indicate other features that may influence design.

Form HYD. 1 Figure 10-5 Example No. 4 Small Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Turner-South No. S-241(6)
Stream name: Bell Coulee Sta. 119+50
County: Blaine Date: 4-9-73
Surveyed By: R. L. Kirschman

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff None
Comment on land use or cover 90% Dryland wheat

Floating debris: None ☐, Light ☒, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☒, Moderate ☐, Severe ☐
Unusual Characteristics

Elev. of water on date of survey Dry
Elev. of low water -, normally dry ☒
Elev. of high water ?, date occured
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☒, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property No if so what elev. will water be allowed to pond
should crossing be designed for fish passage No

SECTION 2 EXISTING STRUCTURE

A. Culvert Size , Type
Condition , Length
B. Bridge: Type
No. of spans , Length of each span ,
, , ,
Clearance
Condition
C. Approximate distance above or below site
Highwater mark elev.
Historical adequacy

Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? Yes, is channel stable ☐, degrading ☒, agrading ☐, unknown ☐ is riprap or bank protection necessary? Yes
Are the following material available locally: Riprap Yes,
Type B & A, Filter Material No. 1 Yes,
No. 2 Yes
Is water or soil alkaline No, acidic No
are sulphates present No
Comments:

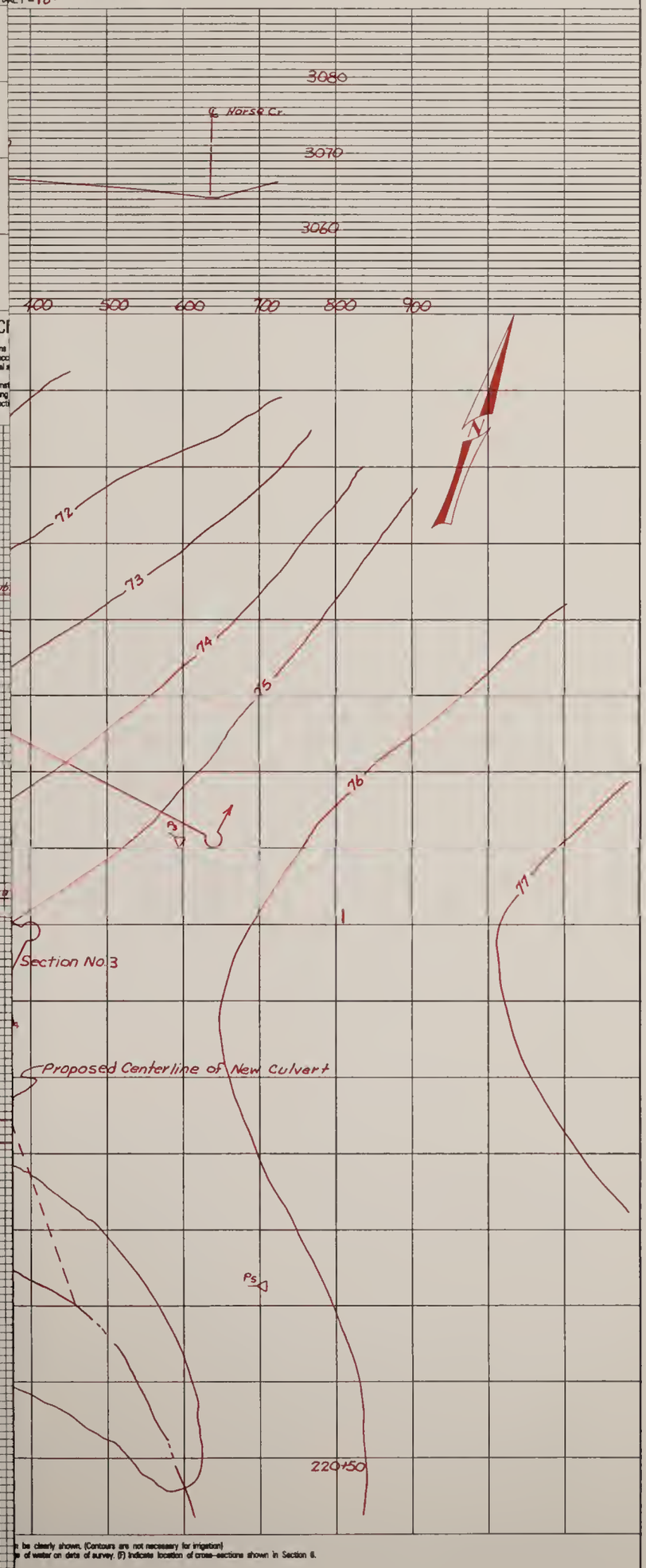
SECTION 4 IRRIGATION DATA

Name of Ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water depth , Bottom width , Side slopes , Total depth
Does ditch carry flood water also?
Flow line elevations of existing structure, inlet outlet

COMMENTS

SECTION 5 LOCATION SKETCH

that will influence the proposed construction.
SCALE: 1" = 10'



SECTION 6 CI

Instructions: Note cross-sections
(3) Vegetation described and acc
In this case, a smaller horizontal s
(A) Provide typical section downst
(C) Provide section under existing
(E) Indicate location of each secti

be clearly shown. (Contours are not necessary for irrigation)
e of water on date of survey. (F) Indicate location of cross-sections shown in Section 6.

Form HYD. 1 Figure 10-5 Example No. 4 Small Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Turner-South — No. S-241(6)
Stream name: Bell Coulee — Sta. 119+50
County: Blaine — Date: 4-9-73
Surveyed By: R. L. Kirschman

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable. See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff: None
Comment on land use or cover: 90% Dryland wheat

Floating debris: None ☐, Light ☒, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☒, Moderate ☐, Severe ☐
Unusual Characteristics

Elev. of water on date of survey: Dry
Elev. of low water: –, normally dry ☒
Elev. of high water: ?, date occured
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☒, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property: No — if so what elev. will water be allowed to reach: –
should crossing be designed for fish passage: No

SECTION 2 EXISTING STRUCTURE

A. Culvert Size , Type
Condition , Length
B. Bridge: Type
No. of spans , Length of each span , , ,
Clearance
Condition
C. Approximate distance above or below site
Highwater mark elev.
Historical adequacy
Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? Yes, is channel stable ☐, degrading ☒, agrading ☐, unknown ☐ is riprap or bank protection necessary? Yes
Are the following material available locally: Riprap Yes, Type B & A, Filter Material No. 1 Yes, No. 2 Yes
is water or soil alkaline No, acidic No
are sulphates present No
Comments:

SECTION 4 IRRIGATION DATA

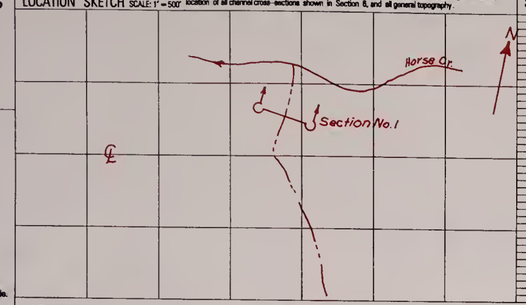
Name of Ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water depth , Bottom width , Side slopes , Total depth
Does ditch carry flood water also?
Flow line elevations of existing structure, inlet outlet

COMMENTS

SECTION 5 LOCATION SKETCH

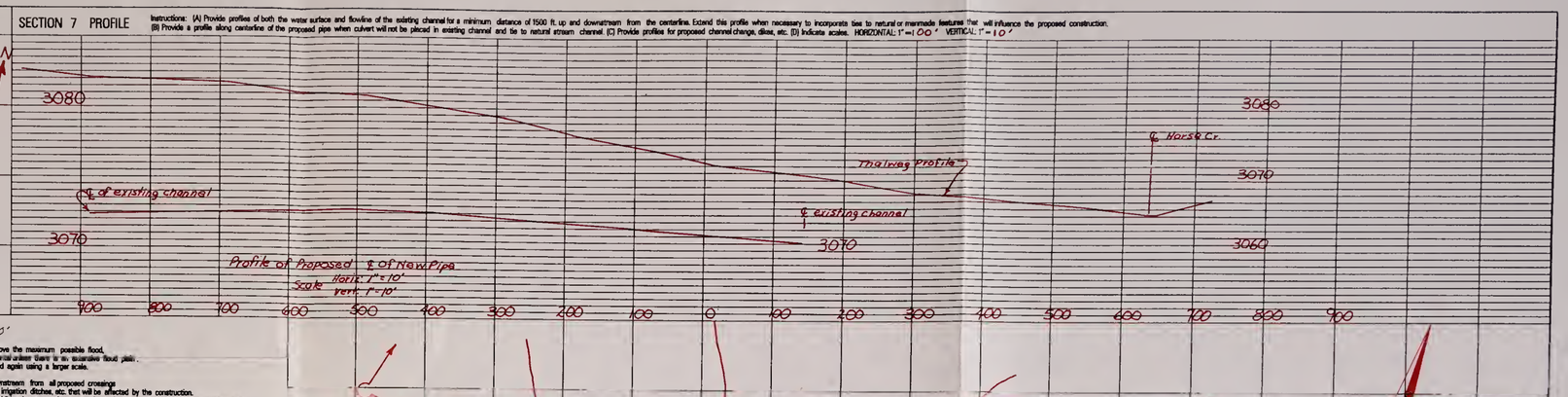
SCALE: 1" = 500'

Instructions: Show centerline of survey, north arrow, general course of stream, existing structures, location of all channel cross-sections shown in Section 8, and all general topography.



SECTION 7 PROFILE

Instructions: (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft. up and downstream from the centerline. Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction. (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel. (C) Provide profiles for proposed channel change, dikes, etc. (D) Indicate scales. HORIZONTAL: 1" = 100' VERTICAL: 1" = 10'

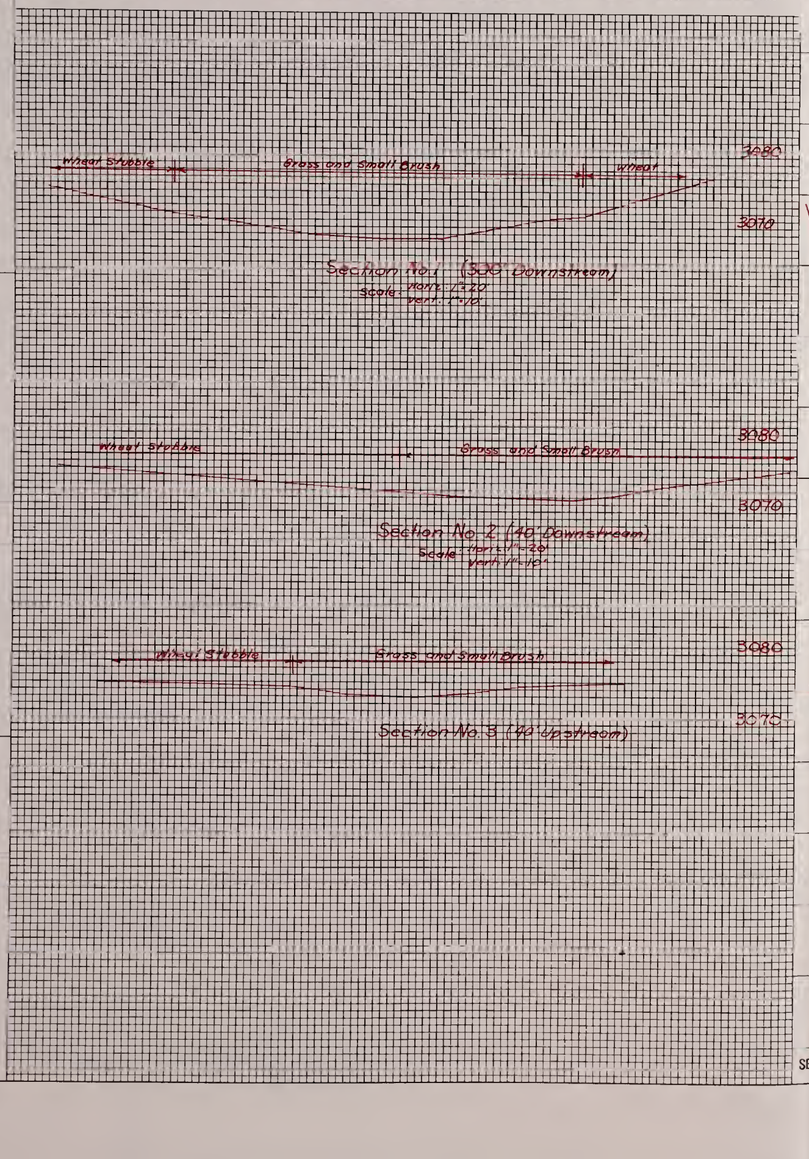

3080
3070
3060
℄ of existing channel
Thalweg Profile
℄ Horse Cr.
Profile of Proposed ℄ of New Pipe
Scale Horiz. 1"=10'
Vert. 1"=10'
900 800 700 600 500 400 300 200 100 0 100 200 300 400 500 600 700 800 900

SECTION 6 CROSS SECTIONS

Scale Horizontal: 1" = 10' Scale Vertical: 1" = 10'

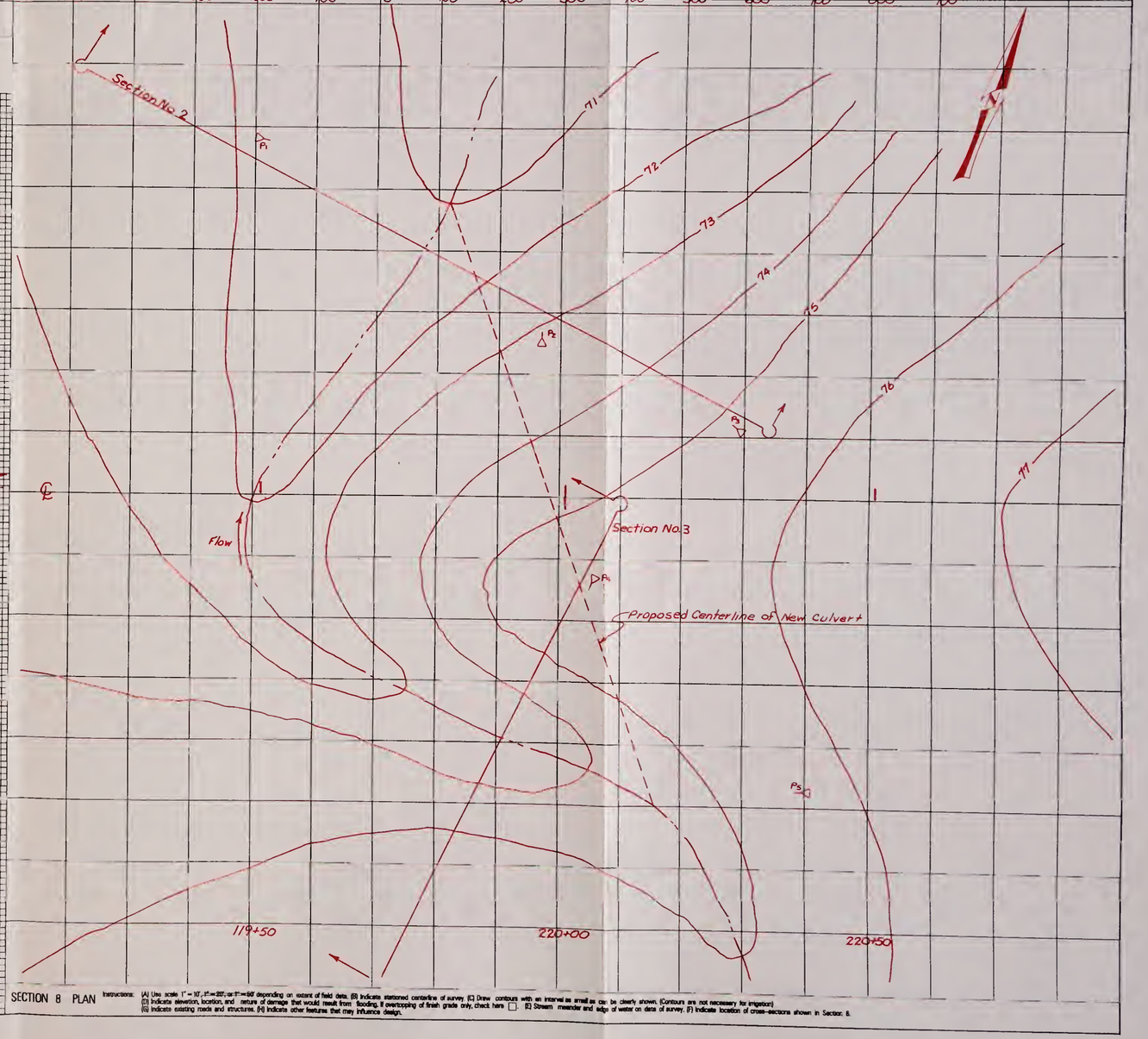
Instructions: Note cross-sections should embody the following general characteristics, (1) Normal to channel, (2) Section extremities to extend well above the maximum possible flood, (3) Vegetation described and accurately located within 3' of all breaklines differences of 0' or greater defined, (5) Use scale of 1" = 5' vertical and horizontal unless there is an excessive flood plain, in this case, a smaller horizontal scale may be used so as to define the flood and low water channel. The low water portion should also be plotted again using a larger scale.

(A) Provide typical section downstream from all proposed structures, (B) Provide cross-section at appropriate construction limits upstream and downstream from all proposed crossings
(C) Provide section under existing bridges to include substructure details, spill-slopes, channel and high water marks (D) Provide typical section of any irrigation ditches, etc. that will be affected by the construction.
(E) Indicate location of each section in Section 5 and 8. (F) Attach photos of each section (G) When there is not enough room on this sheet plot additional cross-sections on a sheet of cross-section paper and attach it to this sheet.



SECTION 8 PLAN

Instructions: (A) Use scale 1" = 10', 1"=20', or 1"=60' depending on extent of field data. (B) Indicate stationed centerline of survey. (C) Draw contours with an interval as small as can be clearly shown. (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding. If overtopping of finish grade only, check here ☐. (E) Stream meander and edge of water on date of survey. (F) Indicate location of cross-sections shown in Section 8. (G) Indicate existing roads and structures. (H) Indicate other features that may influence design.



Form HYD. 1 Figure 10-6 Example No. 5 Small Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Circle-North No. S-13(19)
Stream name: 12 Mile Creek Sta. 319+65
County: McCone Date: 8-11-73
Surveyed By: Warren Reichelt

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff None
Comment on land use or cover Prairie and Rangeland 100%

Floating debris: None ☐, Light ☒, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☒, Moderate ☐, Severe ☐
Unusual Characteristics There is a stock dam 1/4 mile upstream. See comments below.
Elev. of water on date of survey Dry
Elev. of low water –, normally dry ☒
Elev. of high water 2583', date occured 1964
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☒, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property No if so what elev. will water be allowed to reach No
should crossing be designed for fish passage No

SECTION 2 EXISTING STRUCTURE

A. Culvert Size 96", Type S. S. P. P.
Condition Good, Length 80'
B. Bridge: Type
No. of spans , Length of each span
Clearance
Condition
C. Approximate distance above or below site Same Location
Highwater mark elev. 2583'
Historical adequacy This pipe has been adequate although the water has approached the top of the roadway a number of times.
Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? Yes, is channel stable ☐, degrading ☐, agrading ☐, unknown ☒ is riprap or bank protection necessary? Yes
Are the following material available locally: Riprap Yes, Type A or B, Filter Material No. 1 Yes, No. 2 Yes
Is water or soil alkaline No, acidic No
are sulphates present No
Comments:

SECTION 4 IRRIGATION DATA

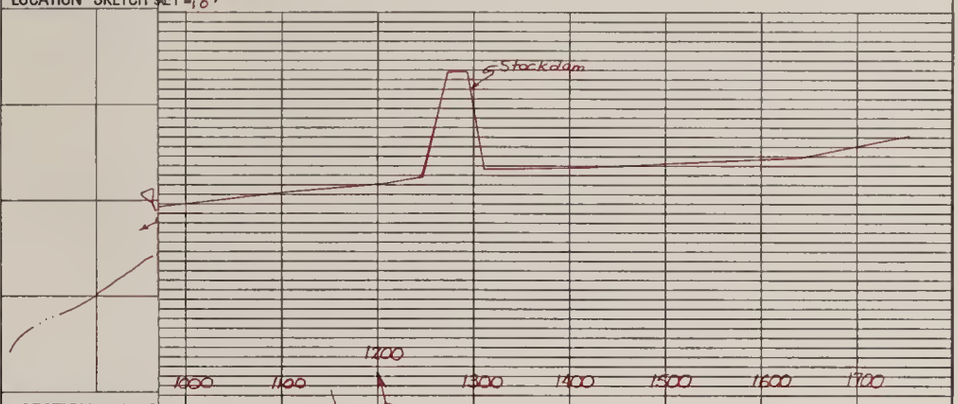
Name of Ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water depth , Bottom width , Side slopes , Total depth
Does ditch carry flood water also?
Flow line elevations of existing structure, inlet outlet

COMMENTS

There is a stock dam 1/4 mile upstream. It was built and is owned by R. W. White of Rural Route 2, Circle. It is a 10' high earth fill dam. The reservoir when full is approx. 5 acres in size. There is no outlet pipe and no spillway. The dam does signs of washing. See photos.

SECTION 5 LOCATION SKETCH

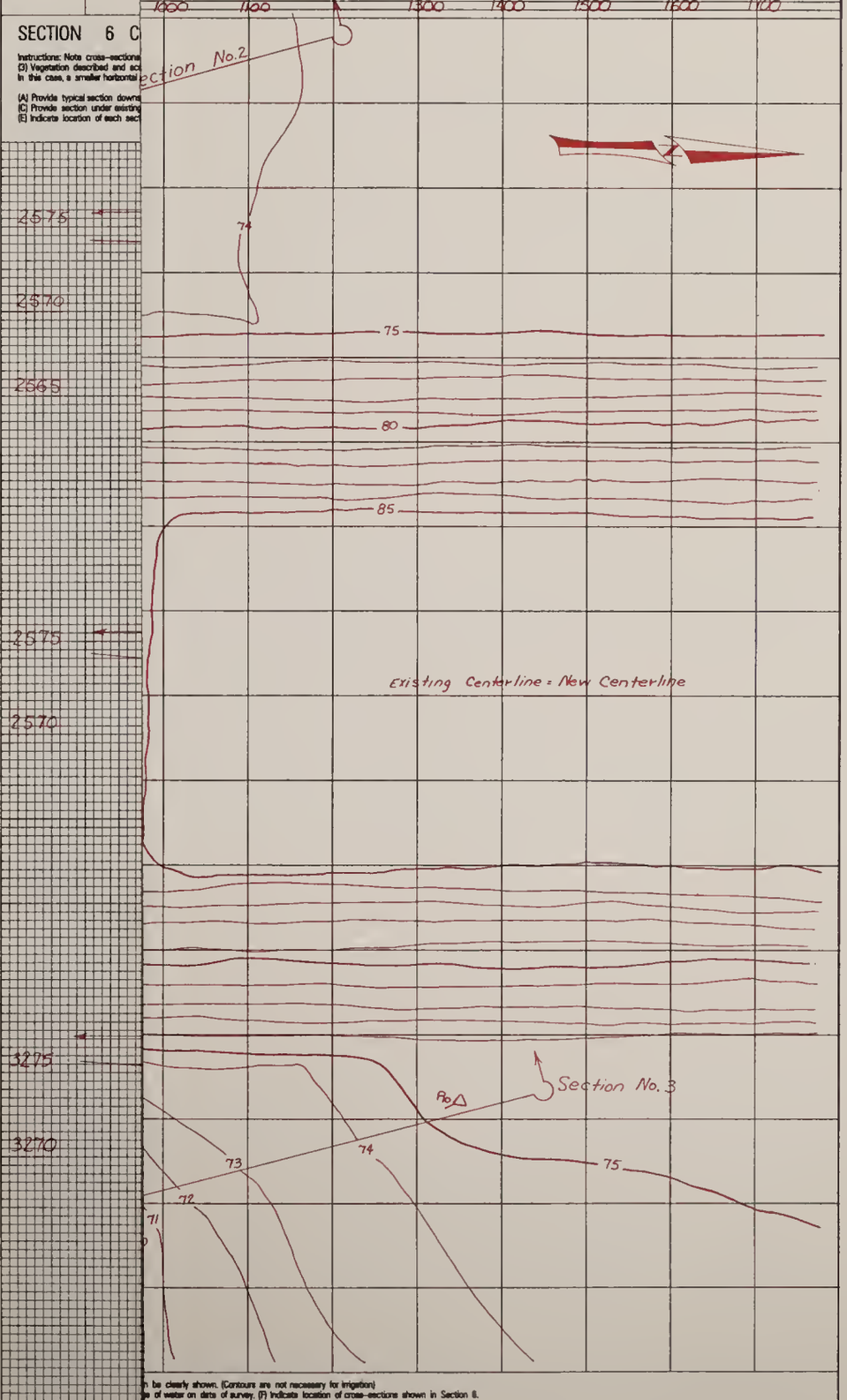
hat will influence the proposed construction.
SCALE 1" = 10'



SECTION 6 C

Instructions: Note cross-sections (S) Vegetation described and sca In this case, a smaller horizontal

(A) Provide typical section downs (C) Provide section under existing (E) Indicate location of each sect



be clearly shown. (Contours are not necessary for irrigation)
e of water on date of survey, (F) Indicate location of cross-sections shown in Section 8.

Form HYD. 1 Figure 10-6 Example No. 5 Small Watershed

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Circle-North No. S-13(19)
Stream name: 12 Mile Creek Sta. 319+65
County: McCone Date: 8-11-73
Surveyed By: Warren Reichelt

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff None
Comment on land use or cover Prairie and Rangeland 100%

Floating debris: None ☐, Light ☒, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☒, Moderate ☐, Severe ☐
Unusual Characteristics There is a stock dam 1/4 mile upstream. See comments below.
Elev. of water on date of survey Dry
Elev. of low water –, normally dry ☒
Elev. of high water 2583[1], date occured 1964
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☒, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property No if so what elev. will water be allowed to reach No
should crossing be designed for fish passage No

SECTION 2 EXISTING STRUCTURE

A. Culvert Size 96", Type S. S. P. P.
Condition Good, Length 80'
B. Bridge: Type
No. of spans , Length of each span ,
, , ,
Clearance
Condition
C. Approximate distance above or below site Same Location
Highwater mark elev. 2583[1]
Historical adequacy This pipe has been adequate although the water has approached the top of the roadway a number of times.
Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? Yes, is channel stable ☐, degrading ☐, agrading ☐, unknown ☒ is riprap or bank protection necessary? Yes
Are the following material available locally: Riprap Yes, Type A or B, Filter Material No. 1 Yes, No. 2 Yes
Is water or soil alkaline No, acidic No, are sulphates present No
Comments:

SECTION 4 IRRIGATION DATA

Name of Ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water depth , Bottom width , Side slopes , Total depth
Does ditch carry flood water also?
Flow line elevations of existing structure, inlet outlet

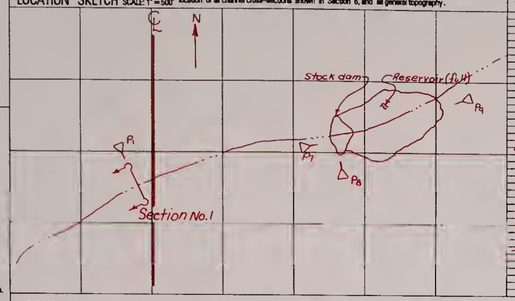
COMMENTS

There is a stock dam 1/4 mile upstream. It was built and is owned by R. W. White of Rural Route 2, Circle. It is a 10' high earth fill dam. The reservoir when full is approx. 5 acres in size. There is no outlet pipe and no spillway. The dam does signs of washing. See photos.

SECTION 5 LOCATION SKETCH

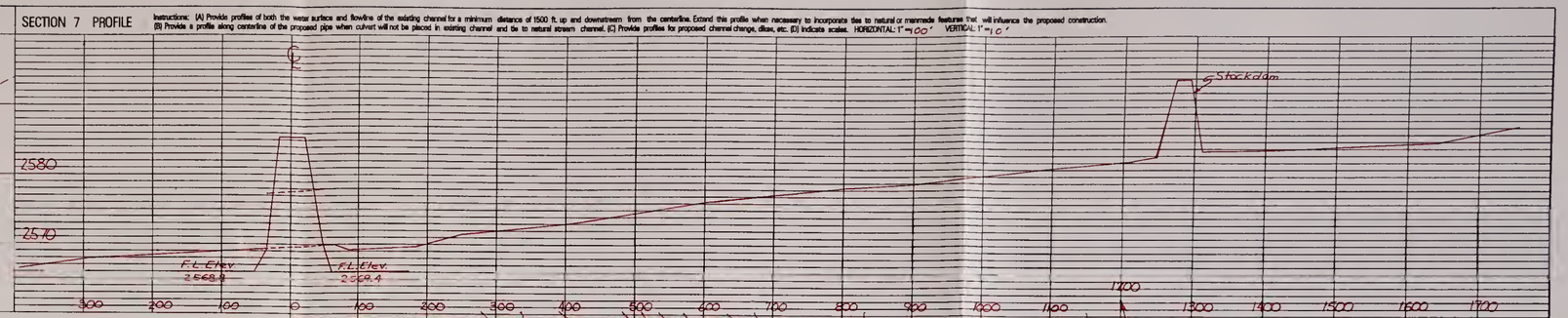
SCALE: 1" = 500'

Instructions: Show centerline of survey, north arrow, general course of stream, existing structures, location of all channel cross-sections shown in Section 6, and all general topography.



SECTION 7 PROFILE

Instructions: (A) Provide profiles of both the wear surface and flowline of the existing channel for a minimum distance of 1500 ft. up and downstream from the centerline. Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction. (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel. (C) Provide profiles for proposed channel change, dikes, etc. (D) Indicate scales. HORIZONTAL: 1" = 100' VERTICAL: 1" = 10'

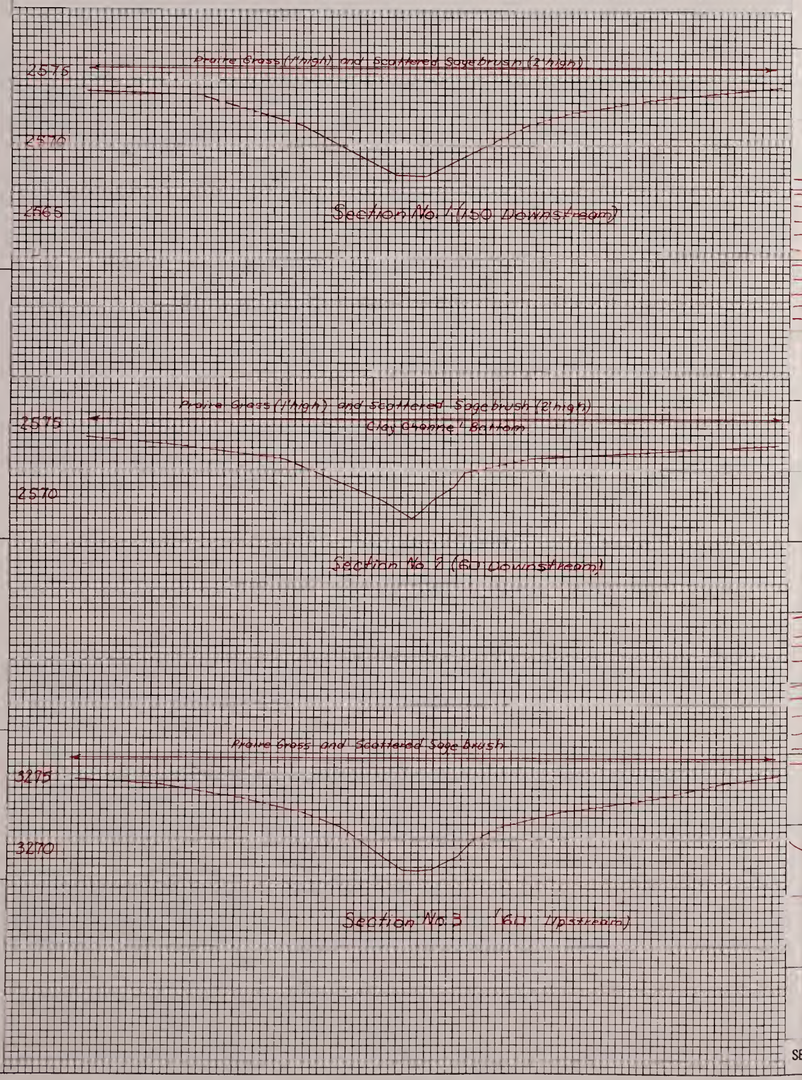


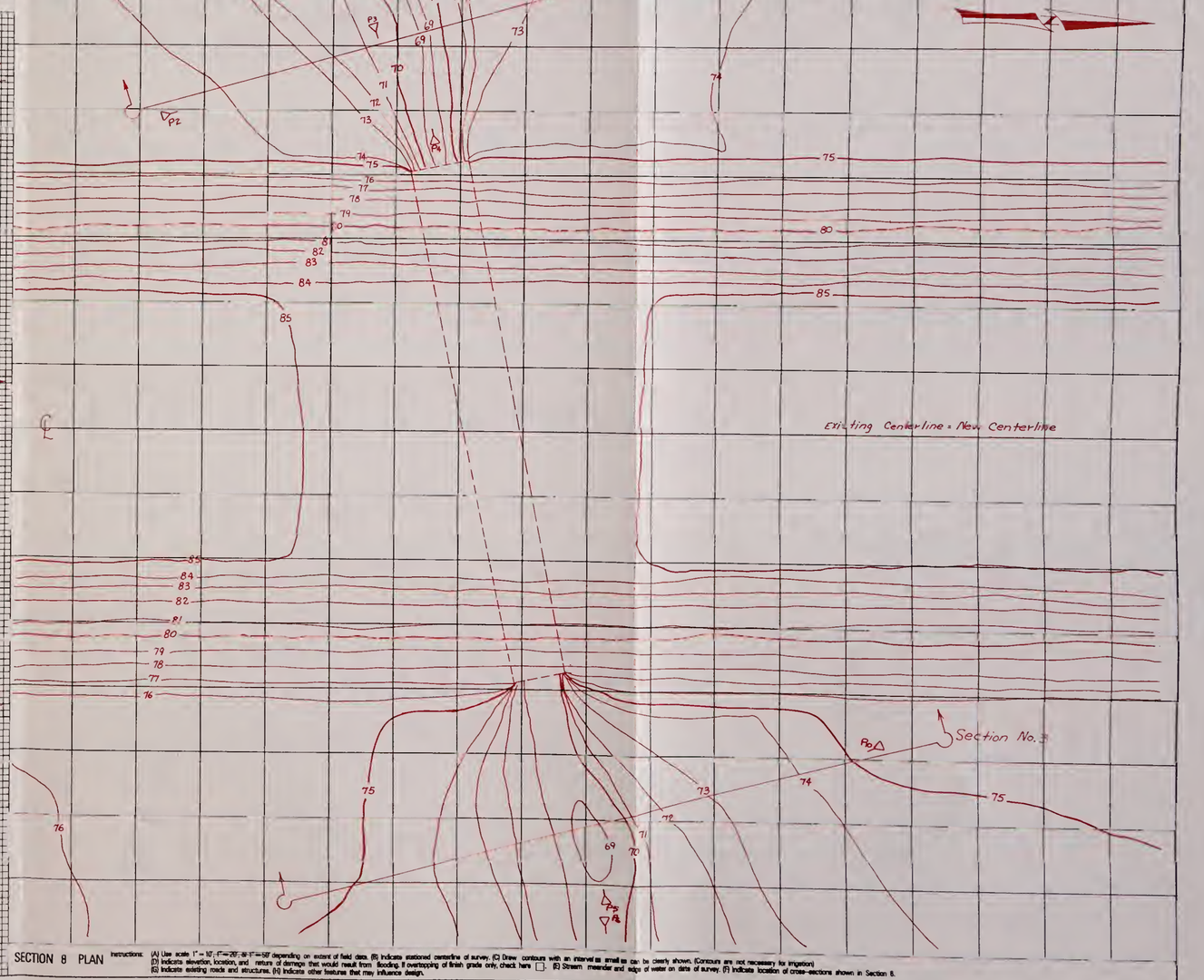
SECTION 6 CROSS SECTIONS

Scale Horizontal: 1" = 10' Scale Vertical: 1" = 5'

Instructions: Note cross-sections should embody the following general characteristics, (1) Normal to channel, (2) Section extremities to extend well above the maximum possible flood, (3) Vegetation described and accurately located within 2', (4) Elevation differences of 6" or greater defined, (5) Use scale at 1" = 10' vertical and horizontal unless there is an extensive flood plain. in this case, a smaller horizontal scale may be used so as to define the flood and low water channel. The low water portion should also be plotted again using a larger scale.

(A) Provide typical section downstream from all proposed structures, (B) Provide cross-section at approximate construction limits upstream and downstream from all proposed crossings (C) Provide section under existing bridges to include substructure detail, spill-slopes, channel and high water marks (D) Provide typical section of any irrigation ditches, etc. that will be affected by the construction. (E) Indicate location of each section in Section 5 and 8. (F) Attach photos of each section (G) When there is not enough room on this sheet plot additional cross-sections on a sheet of cross-section paper and attach it to this sheet.





SECTION 8 PLAN

Instructions: (A) Use scale 1" = 10', 1" = 20', or 1" = 50' depending on extent of field data. (B) Indicate stationed centerline of survey. (C) Draw contours with an interval as small as can be clearly shown. (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding. If overtopping of finish grade only, check here ☐. (E) Stream meander and edge of water on date of survey. (F) Indicate location of cross-sections shown in Section 8. (G) Indicate existing roads and structures. (H) Indicate other features that may influence design.

Form HYD. 1 Figure 10-7 Example No. 6 Complex Irrigation

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Fairfield E & W No. F-65(7)
Stream name: Rosenfield Ditch Sta. 187+45
County: Teton Date: 2-30-72
Surveyed By: C. Pell

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Estimated drainage area _____ Acres or Square miles
Area not contributing to runoff _____
Comment on land use or cover _____

Floating debris: None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris _____
Ice Light ☐, Moderate ☐, Severe ☐
Unusual Characteristics _____

Elev. of water on date of survey _____
Elev. of low water _____, normally dry ☐
Elev. of high water _____, date occured _____
Cause Backwater from ice ☐, Backwater from Construction ☐
Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property _____ if so what elev. will water be allowed to reach _____
should crossing be designed for fish passage _____

SECTION 2 EXISTING STRUCTURE

A. Culvert Size _____, Type _____
Condition _____, Length _____
B. Bridge: Type Flat Slab Concrete
No. of spans 1, Length of each span 260',
_____, _____, _____
Clearance (Flowline to low beam) 4.5'
Condition Fair (Some concrete is scaling)
C. Approximate distance above or below site Some site
Highwater mark elev. _____
Historical adequacy Adequate
Comments _____

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No, is channel stable ☐, degrading ☐, agrading ☐, unknown ☐ is riprap or bank protection necessary? No
Are the following material available locally: Riprap Yes, Type A or B, Filter Material No. 1 Yes, No. 2 Yes
Is water or soil alkaline No, acidic No
are sulphates present No
Comments: _____

SECTION 4 IRRIGATION DATA

Name of Ditch Greenfield Ditch
Owner Greenfield Irrigation Co.
Address of ditch company Fairfield Mont.
Ditch capacity 60 cfs, Slope .0008, Water depth 3.5', Bottom width 10.0', Side slopes 2:1, Total depth _____
Does ditch carry flood water also? No
Flow line elevations of existing structure, inlet _____ outlet _____

COMMENTS

Greenfield Irrigation Co. said they felt a culvert was unacceptable for this crossing. They also said they require 12" minimum freeboard on all bridges crossing their canals.

SECTION 5 LOCATION SKETCH

that will influence the proposed construction.
CAL: 1" =

Green... See attached sheet for profiles of field Ditches
Main...
Field Di...

W.S. Profile on date of survey

4000
3995
3990
400 500 600 700 800 900 1000 1100

SECTION 6 C

Instructions: Note cross-sections
(3) Vegetation described and ac
In this case, a smaller horizonta

(A) Provide typical section down
(C) Provide section under existin
(E) Indicate location of each sec

3995
Section No 1
3990
4000
3995
3990
ridge
3995
Section No 2
℄ of survey = ℄ PTW
3990
3995
3990
P6
P16
Section No.5
P11 Combination Turnout and Division Box
P13
P7
P8
Field Ditch No.2
P10
Inlet Elev. 3992.1
3995
P9
Section No.7
P12
Section No.6
3990
Field Ditch No.3
188+00

...en be clearly shown. (Contours are not necessary for irrigation)
...ge of water on date of survey. (F) Indicate location of cross-sections shown in Section 8.

Form HYD. 1 Figure 10-7 Example No. 6 Complex Irrigation

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: Fairfield E & W No. F-65(7)
Stream name: Rosenfield Ditch Sta. 187+45
County: Teton Date: 2-30-72
Surveyed By: C. Pell

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled, indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Estimated drainage area _____ Acres or Square miles
Area not contributing to runoff _____
Comment on land use or cover _____

Floating debris: None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris _____
Ice Light ☐, Moderate ☐, Severe ☐
Unusual Characteristics _____

Elev. of water on date of survey _____
Elev. of low water _____, normally dry ☐
Elev. of high water _____, date occured _____
Cause Backwater from ice ☐, Backwater from Construction ☐
Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property _____ if so what elev. will water be allowed to reach _____
should crossing be designed for fish passage _____

SECTION 2 EXISTING STRUCTURE

A. Culvert Size _____, Type _____
Condition _____, Length _____
B. Bridge: Type Flat Slab Concrete
No. of spans 1, Length of each span 260',
Clearance (Flowline to low beam) 4.5'
Condition Fair (Some concrete is scaling)
C. Approximate distance above or below site Same site
Highwater mark elev. _____
Historical adequacy Adequate
Comments _____

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No, is channel stable ☐, degrading ☐, agrading ☐, unknown ☐ is riprap or bank protection necessary? No
Are the following material available locally: Riprap Yes, Type A or B, Filter Material No. 1 Yes, No. 2 Yes
Is water or soil alkaline No, acidic No
are sulphates present No
Comments: _____

SECTION 4 IRRIGATION DATA

Name of Ditch Greenfield Ditch
Owner Greenfield Irrigation Co.
Address of ditch company Fairfield Mont.
Ditch capacity 60 cfs, Slope .0008, Water depth 3.5', Bottom width 10.0', Side slopes 2:1, Total depth _____
Does ditch carry flood water also? No
Flow line elevations of existing structure, inlet _____ outlet _____

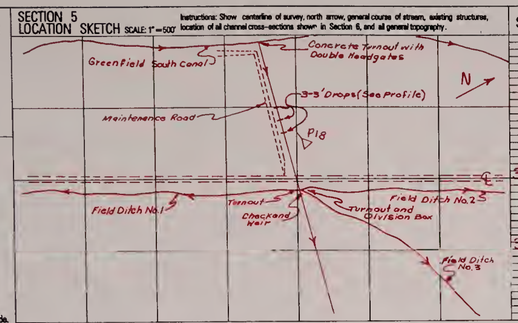
COMMENTS

Greenfield Irrigation Co. said they felt a culvert was unacceptable for this crossing. They also said they require 12" minimum freeboard on all bridges crossing their canals.

SECTION 5 LOCATION SKETCH

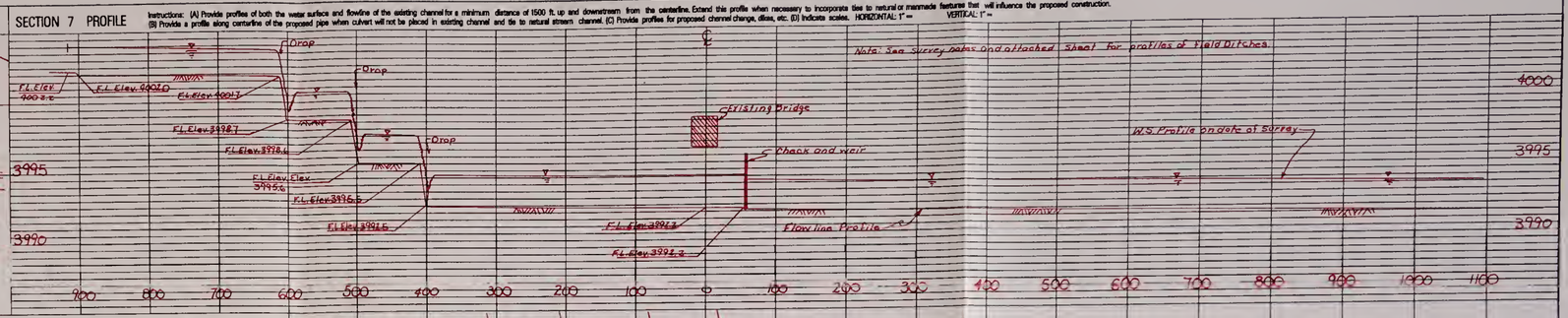
SCALE: 1" = 500'

Instructions: Show centerline of survey, north arrow, general course of stream, existing structure, location of all channel cross-sections shown in Section 6, and all general topography.



SECTION 7 PROFILE

Instructions: (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft. up and downstream from the centerline. Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction. (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel. (C) Provide profiles for proposed channel change, dikes, etc. (D) Indicate scales. HORIZONTAL: 1" = VERTICAL: 1" =

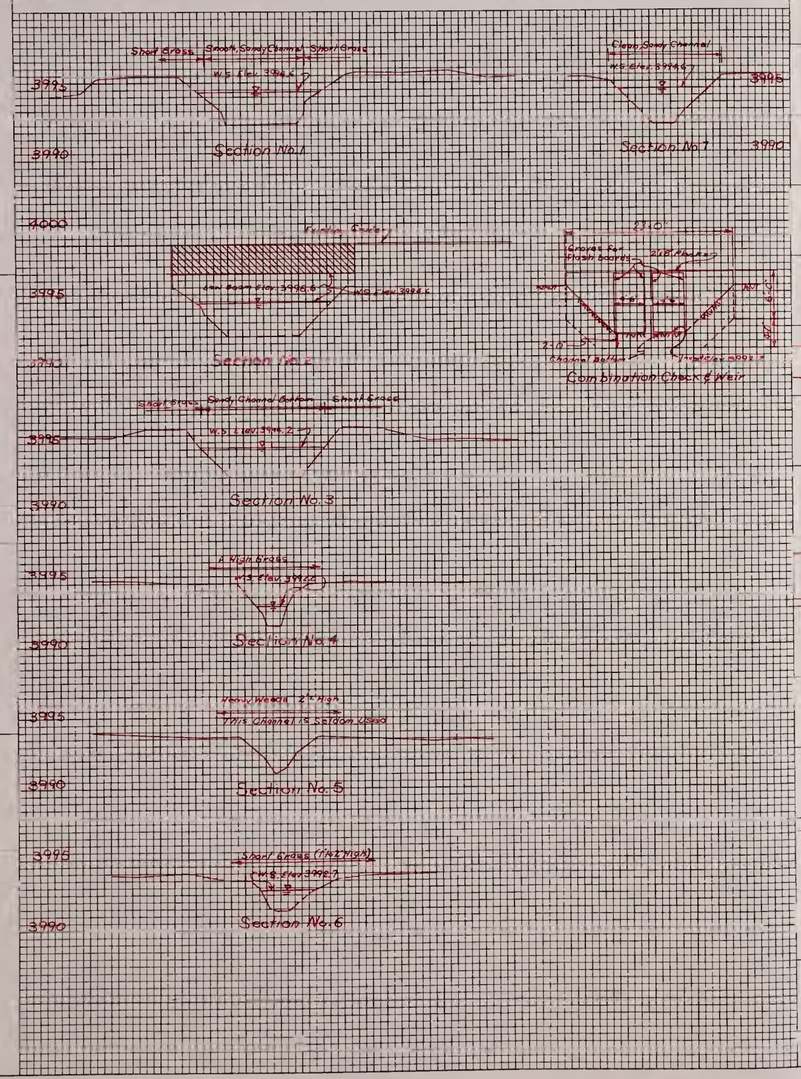


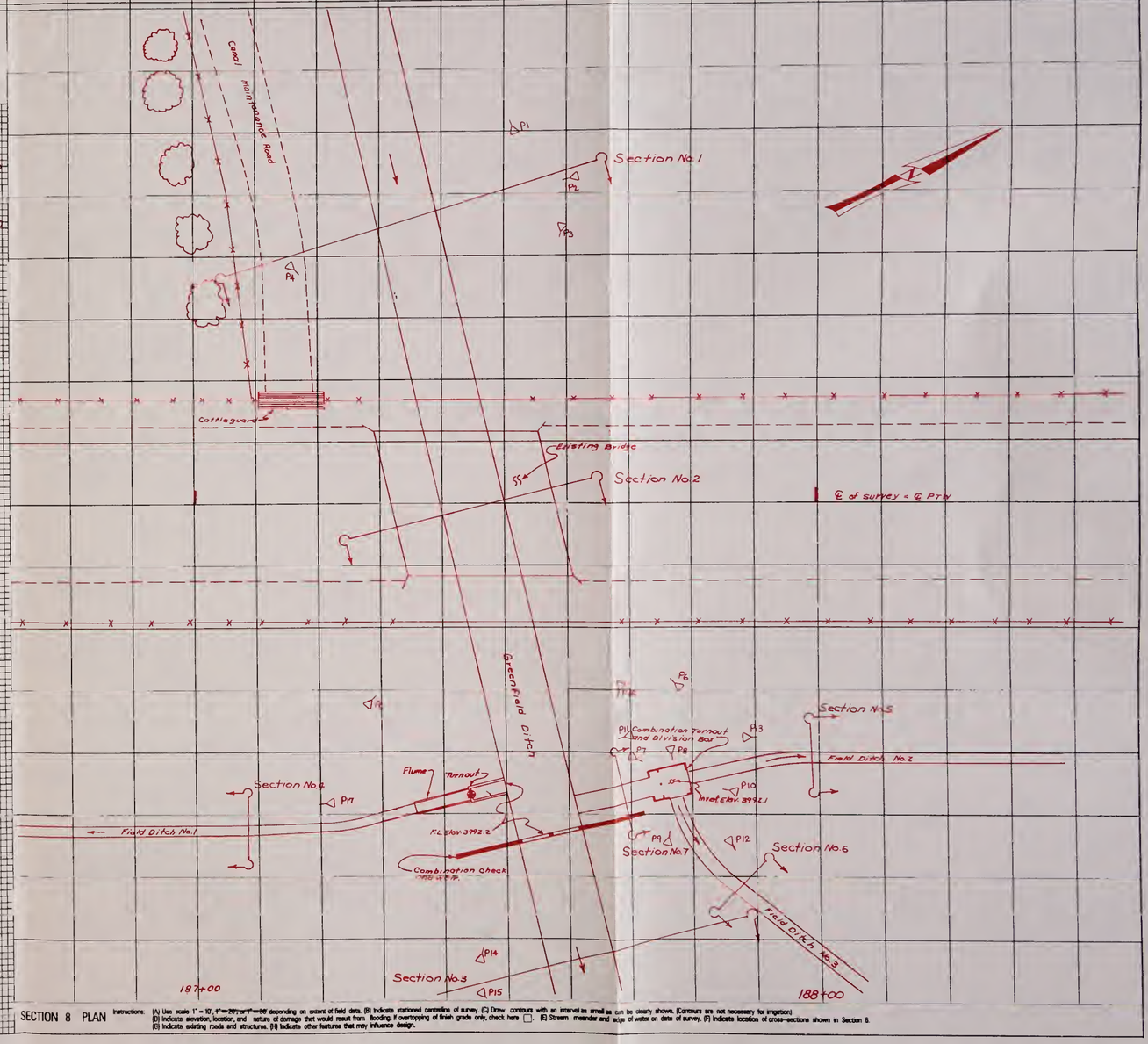
SECTION 6 CROSS SECTIONS

Scale Horizontal: 1" = 10' Scale Vertical: 1" = 5'

Instructions: Note cross-sections should embody the following general characteristics. (1) Normal to channel, (2) Section extremities to extend well above the maximum possible flood, (3) Vegetation described and accurately located within 2', (4) Elevation differences of 0' or greater defined, (5) Use scale at 1" = 10' vertical and horizontal unless there is an extensive flood plain. In this case, a smaller horizontal scale may be used so as to define the flood and low water channel. The low water portion should also be plotted again using a larger scale.

(A) Provide typical section downstream from all proposed structures, (B) Provide cross-section at appropriate construction limits upstream and downstream from all proposed crossings (C) Provide section under existing bridges to include substructure details, spill-slopes, channel and high water marks (D) Provide typical section of any irrigation ditches, etc. that will be affected by the construction. (E) Indicate location of each section in Section 5 and 8. (F) Attach photos of each section (G) When there is not enough room on this sheet plot additional cross-sections on a sheet of cross-section paper and attach it to this sheet.





SECTION 8 PLAN

Instructions: (A) Use scale 1" = 10', 1"=20', or 1"=50' depending on extent of field data. (B) Indicate stationed centerline of survey. (C) Draw contours with an interval as small as can be clearly shown. (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding. If overtopping of finish grade only, check here ☐. (E) Stream meander and edge of water on date of survey. (F) Indicate location of cross-sections shown in Section 6. (G) Indicate existing roads and structures. (H) Indicate other features that may influence design.

Form HYD. 1 Figure 10-8 Example No. 7 Simple Irrigation

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

Project: White Sulpher Spring - East No. F-8 (17)
Stream name: Brown's Ditch Sta. 39+50
County: Meagher Date: 12-25-72
Surveyed By: R. Hoffman

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION.

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing.
3. Comments of local residents will aid in filling out much of this information. The division lab may be of some help when filling out Section 3.
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4. Attach any right-of-way agreements if they have been made.
5. Submit all survey notes with this sheet.
6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and of all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff _____
Comment on land use or cover _____

Floating debris: None ☐ , Light ☐ , Medium ☐ , Heavy ☐
Other ☐ , Quantity of Debris _____
Ice Light ☐ , Moderate ☐ , Severe ☐
Unusual Characteristics _____

Elev. of water on date of survey _____
Elev. of low water _____ , normally dry ☐
Elev. of high water _____ , date occured _____
Cause Backwater from ice ☐ , Backwater from Construction ☐ , Cloudburst ☐ , Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property _____ if so what elev. will water be allowed to reach _____
should crossing be designed for fish passage _____

SECTIDN 2 EXISTING STRUCTURE

A. Culvert Size 24" , Type C.S.P.-Sq. ends
Condition Good , Length 34'
B. Bridge: Type _____
No. of spans _____ , Length of each span _____ , _____ , _____ , _____
Clearance _____
Condition _____
C. Approximate distance above or below site 10' downstream
Highwater mark elev. -
Historical adequacy Adequate

Comments See photos for details of turnout and division box.

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No , is channel stable ☒ , degrading ☐ , agrading ☐ , unknown ☐ is riprap or bank protection necessary? No
Are the following material available locally: Riprap Yes , Type B , Filter Material No. 1 Yes , No. 2 Yes
Is water or soil alkaline No , acidic No
are sulphates present No
Comments: _____

SECTION 4 IRRIGATION DATA

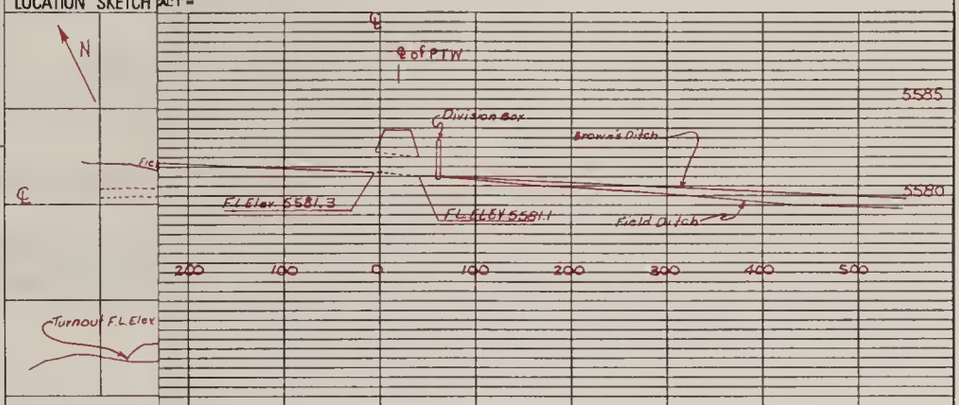
Name of Ditch Brown's Ditch
Owner Tom Brown
Address of ditch company Route 2, White Sulpher Springs
Ditch capacity 600 miners inch, Slope 0.03 ' /' , Water depth 1.5' , Bottom width 20' , Side slopes 1:1 , Total depth 2.5'
Does ditch carry flood water also? No
Flow line elevations of existing structure, inlet 5581.3 outlet 5581.1

COMMENTS

_____

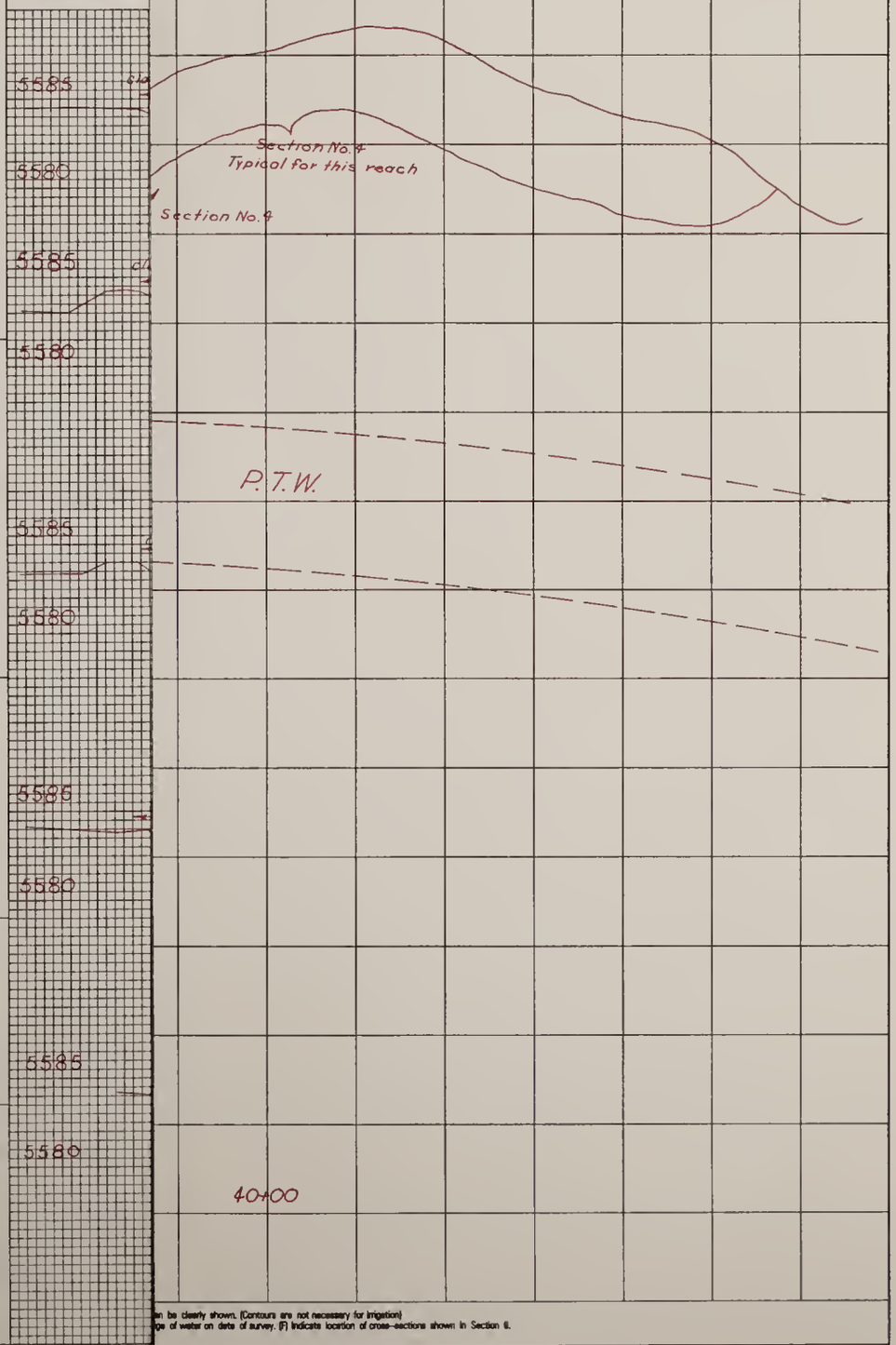
SECTION 5 LOCATION SKETCH

that will influence the proposed construction.
AL: 1" =



SECTION 6 C

Instructions: Note cross-section
(3) Vegetation described and
In this case, a smaller horizontal
(A) Provide typical section down
(C) Provide section under existin
(E) Indicate location of each se



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Form HYD. 1 Figure 10-8 Example No. 7 Simple Irrigation

MONTANA DEPARTMENT OF HIGHWAYS

SURVEY DATA FOR DESIGN OF WATERWAYS

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GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable. See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples.
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6. Submit photographs of all channel and overbank areas, and all existing structures. Be sure they are well labeled. Indicate the location and or all photographs with an arrow(>) in Section 8.

Section 1 WATERSHED DATA

Area not contributing to runoff _____
Comment on land use or cover _____

Floating debris: None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris _____
Ice Light ☐, Moderate ☐, Severe ☐
Unusual Characteristics _____

Elev. of water on date of survey _____
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Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property _____ If so what elev. will water be allowed to reach _____
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SECTION 2 EXISTING STRUCTURE

A. Culvert Size 24", Type C. S. P. - Sq. ends
Condition Good, Length 34'
B. Bridge: Type _____
No. of spans _____, Length of each span _____, _____, _____
Clearance _____
Condition _____
C. Approximate distance above or below site 10' downstream
Highwater mark elev. –
Historical adequacy Adequate

Comments See photos for details of turnout and division box.

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Do banks or bed show scour? No, is channel stable ☑, degrading ☐, agrading ☐, unknown ☐ is riprap or bank protection necessary? No
Are the following material available locally: Riprap Yes, Type B, Filter Material No. 1 Yes, No. 2 Yes
Is water or soil alkaline No, acidic No
are sulphates present No
Comments: _____

SECTION 4 IRRIGATION DATA

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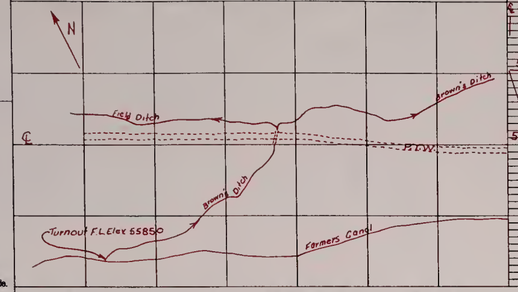
Owner Tom Brown
Address of ditch company Route 2, Okonite/Sulpher Springs
Ditch capacity 600 miners inch, Slope 0.03 ' /, Water depth 1.5', Bottom width 20', Side slopes 1:1, Total depth 2.5'
Does ditch carry flood water also? No
Flow line elevations of existing structure, inlet 5581.3 outlet 5581.1

COMMENTS _____

SECTION 5 LOCATION SKETCH

SCALE: 1" = 500'

Instructions: Show centerline of survey, north arrow, general course of stream, existing structures, location of all channel cross-sections shown in Section 8, and all general topography.



SECTION 7 PROFILE

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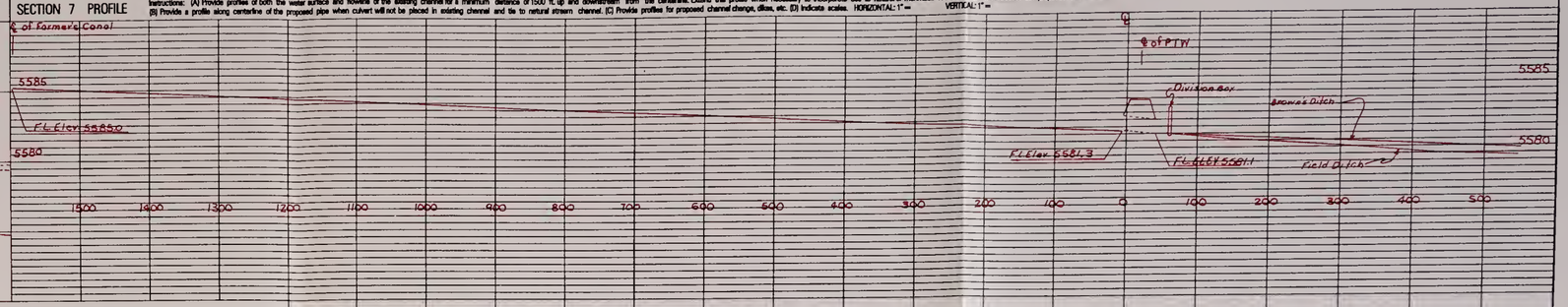

SECTION 6 CROSS SECTIONS

Scale Horizontal: 1" = 5' Scale Vertical: 1" = 5'

Instructions: Note cross-sections should embody the following general characteristics, (1) Normal to channel, (2) Section extremities to extend well above the maximum possible flood, (3) Vegetation described and accurately located within 2', (4) Elevation differences of 0' or greater defined, (5) Use scale at 1" = 10' vertical and horizontal unless there is an extensive flood plain. In this case, a smaller horizontal scale may be used so as to define the flood and low water channel. The low water portion should also be plotted again using a larger scale.

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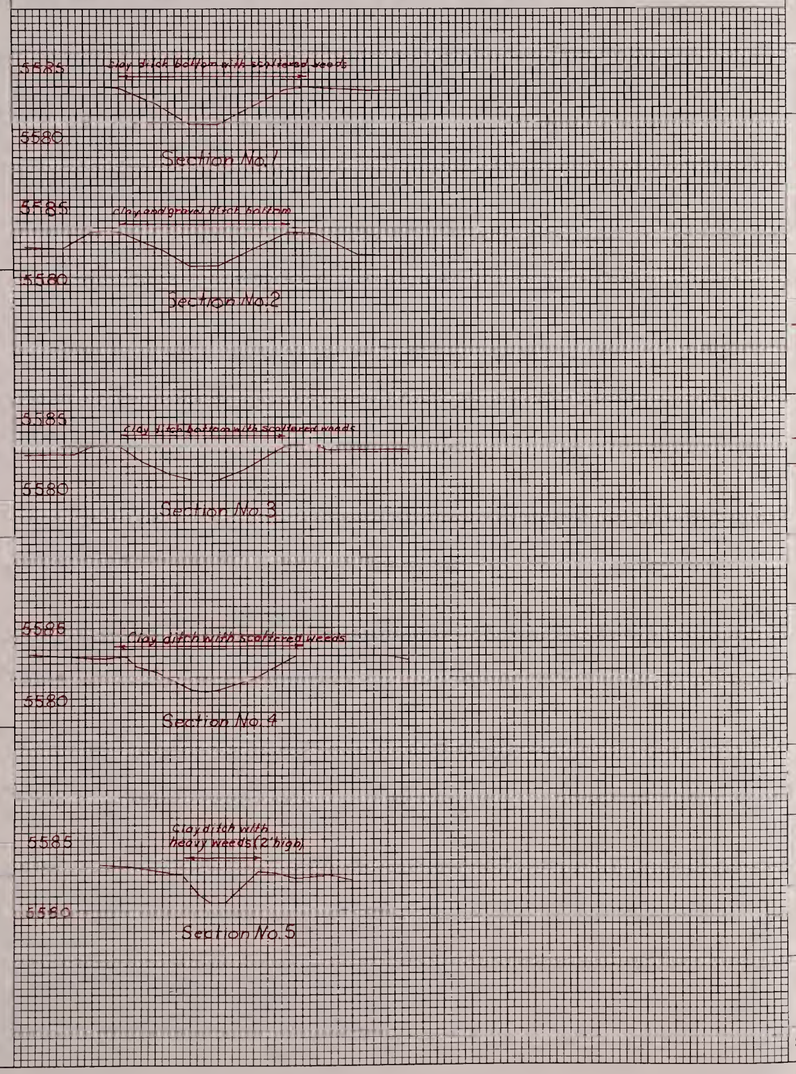


SECTION 8 PLAN

Instructions: (A) Use scale 1" = 10', 1" = 20', or 1" = 50' depending on extent of field data. (B) Indicate stationed centerline of survey. (C) Draw contours with an interval as small as can be clearly shown. (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding. If overtopping of finish grade only, check here ☐. (E) Stream meander and edge of water on date of survey. (F) Indicate location of cross-sections shown in Section 8. (G) Indicate existing roads and structures. (H) Indicate other features that may influence design.

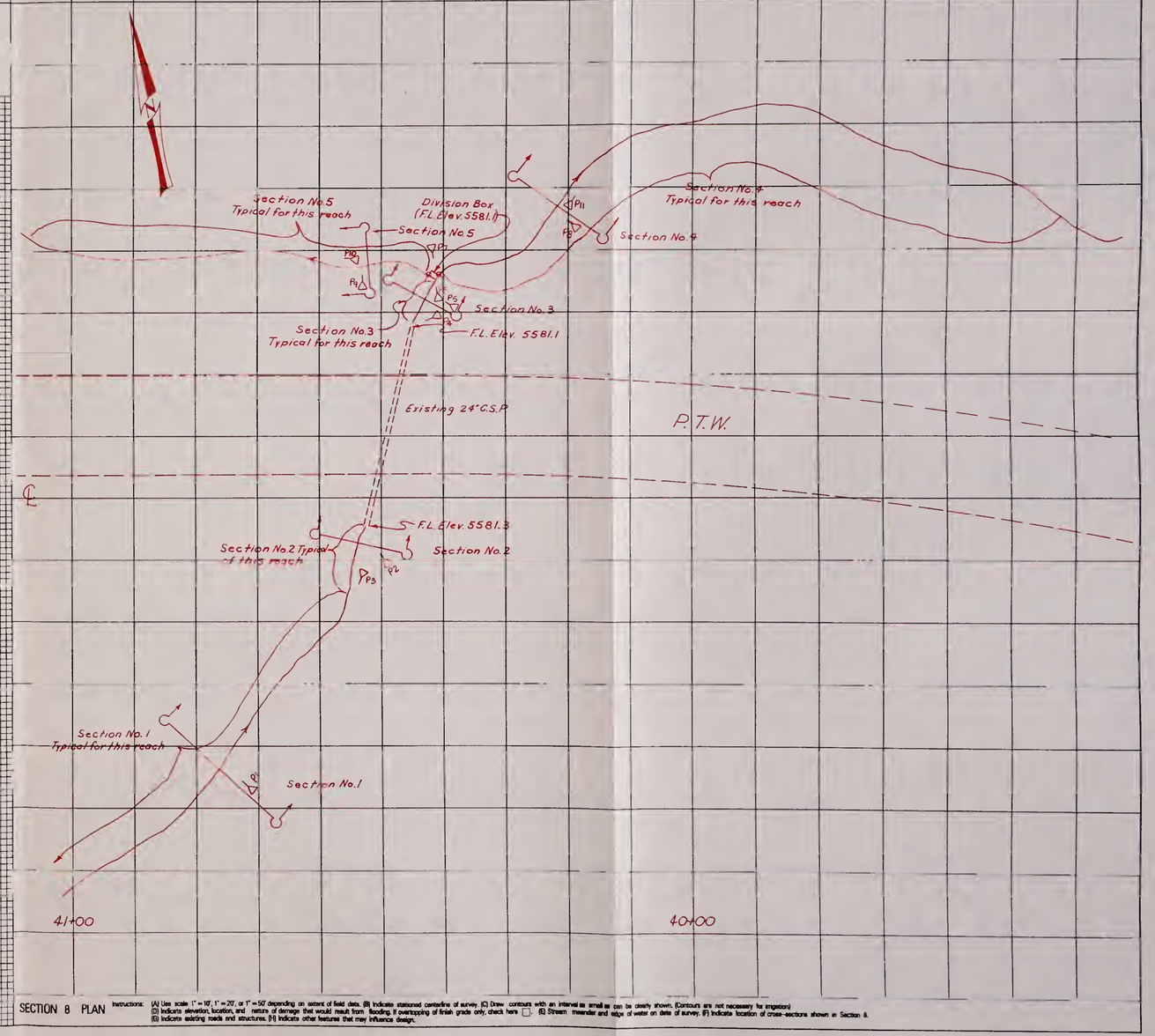


Figure 10-9
Example Form HYD-2

MONTANA DEPARTMENT OF HIGHWAYS

WATER WELL INFORMATION
(To be completed and sent to the Hydraulics Unit)

Project Name _____ No. _____

Well Location (Tie to highway stationing) _____
_____

Well Information

Describe Casing _____
_____
Describe Perforations _____
_____
Was Casing Left in Place? _____
Describe Screens _____
_____
Were Screens Left in Place? _____
Elevation at the Top of the Well (Nearest tenth of a foot) _____
Depth of Well _____

Water Information

Depth to Static Water Level _____
Test Pump Used: Manufacturer _____, Model No. _____
H.P. _____, Type of Pump _____
Date of Test Pumping _____
Does Water Table Fluctuate with Seasons? _____
Test Pumping Log:

Date	Time	Pumping Rate	Depth to Water	Remarks

Reason for ending test pump (well should be test pumped until capacity is reached or 70 GPM are attained) _____
_____

Attach a copy of the well log required by the Montana Water Resources Board and a copy of the water quality tests.

Any comments or additional information that might be pertinent to the development of this well should be written on another sheet and attached.

Table of Contents

Chapter Eleven — Notekeeping

Survey Notes 11-1

Definitions 11-1

Importance 11-1

Uses 11-2

Keeping Notes 11-2

Elements of Notes 11-2
Title Page 11-2
Sketch, Notes and Diagrams 11-2

Record Information 11-2

Pointings, Observations and Measurements 11-3

Descriptions 11-4
Importance 11-4
Practice 11-4
Elements 11-4

Delineation 11-5
Delineation 11-5
Drawing Sketch Notes 11-5

Construction Surveys 11-6

Horizontal Control — Centerline 11-6

Cross-Section Notes 11-6

Major Structures 11-7

Minor Structures 11-7

Common Errors in Notekeeping 11-7
Plus and Minus Rods 11-7
Distance Out of Sequence 11-8
Catch Point Not Defined 11-8
Excavation without Centerline 11-8
Wrong HI 11-8
HI in Wrong Column 11-8
Decimal Points 11-8

Corrections to Notes 11-8

Data Transmittal 11-9

Disposition and Use of Notes 11-9

Handling 11-9

Indexing and Checking 11-9

Submittal 11-10

Sample Notes 11-10

Figures

11-1 Field Note Check List 11-11

Chapter Eleven
Notekeeping

Survey Notes

Definitions

Field survey notes are complete graphic, tabular, written or electronically coded survey records that depict each step of the survey. They enable knowledgeable people to interpret and use the survey and its results and retrace the footsteps of the surveyor. The minimum information in survey notes includes:

- survey location;
- diagrams or sketches;
- pertinent record information and references;
- consecutive page numbers in the upper right hand corner;
- original "raw" data values (without any mathematical manipulations and without any corrections for errors) of distance, angle, and elevations;
- measurements of pertinent atmospheric conditions, such as temperature, pressure and ppm settings;
- monuments found or set, and complete descriptions — e.g. 5/8-inch rebar with 1 1/2-inch plastic yellow cap stamped "4378S";
- title page for each day;
- explanatory notes about any condition(s) that might affect the accuracy or result of the survey; and
- any items the party chief feels are pertinent.

Importance

Field notes are not an accessory to the survey — they are an integral part of the survey. A survey is never completed until field notes are submitted for checking and filing.

Field notes perpetuate a survey even when stakes have rotted and monuments are obliterated.

Field notes, together with diaries and survey party reports, are occasionally the primary source of the Department's documentation in court cases arising between the Department and landowners or contractors. For this reason, measured values are ***never*** to be erased. If a numerical value is wrong, cross it out. Original field notes should not be copied, unless there is a very good reason. Copied notes will always be labeled "COPY," and the reason will be shown. If notes are copied, the originals will always be retained.

In view of the importance of the field notes, the duties should always be assigned to a knowledgeable member of the party. The notekeeper should have a thorough understanding of the purpose of the survey and the operations.

Survey field notes serve as an interpretable field record of a survey party's every step in the prosecution of a survey.

Uses

The field notes are used by the survey party to record all measurements made in the field and to show lines and points established or found.

The notes are often used by others to check the accuracy of the survey, adjust the survey and derive best values, and to extract data for other surveys. They are also the primary basis for most design, traffic, right of way, construction, and other engineering measurements.

Keeping Notes

Elements of Notes

Title Page

Filing and subsequent use of field notes is facilitated by a title page. A title page contains a summary for a set of field notes. Each day's notes will begin with a title page. Information included on the title page should identify the project number, control number, type of survey, crew members and their duties, instruments used including serial numbers, and weather conditions. Other information that will aid someone searching for specific survey information may also be added. By the time a project survey is completed, there may be numerous books and forms filed. Well-indexed notes will save time and expense when they are searched for details.

Sketch, Notes and Diagrams

Some entries are made primarily for aiding in the interpretation of the measured values. These include:

- a north arrow, always shown on each page where a sketch is used;
- planimetric features;
- standard mapping delineation lines, symbols, numerals, and letters; and
- descriptive notes and datums.

Record Information

Record data are defined as that information that can be retrieved from formal filing systems.

Some samples of record data are: coordinates, stations, survey data, point descriptions, bearings, or azimuths (with basis given), and elevations.

Record information comes from such sources as control survey maps, field survey notes, corner recordations, certificates of survey, construction plans, and government data sheets.

Most of the record information should be assembled prior to the field survey. Where practical, the source or authority should be cited for the acceptance and use of any found point.

A "record monument" is one that is identified as being authentic and has been proved to occupy its original position. A record monument and its corroborating description by the notekeeper are a part of the record information of the survey.

The word "found" is always used in describing recovered points. However, all found points are not necessarily record monuments to the notekeeper. That is, the party might find points for which it does not have any substantiating information. The notes will describe the details of the found point so that it could be described on a recorded document.

Calculated data result from mathematical manipulation of measured values. Whenever a calculated value is shown, also show the record or measured values that are the basis of the calculation. For example, if an angle is turned by repetition six times with a one-minute theodolite, the recording of the mean of the six winds is not adequate. Enter the circle reading for one, three, and six repetitions. Also, enter the coordinates of both points between which an inverse has been calculated or the store numbers used in the project coordinate list.

When survey monuments are set, include in the field notes adequate evidence of the setting. Document any mark of major significance with a definitive description. Evidence all points of less significance, such as a line of concrete nails at even stations by an entry in the notes as, "CNs set fl, in pvmt on full stas." Keep a list of abbreviations used at the beginning of all books.

In a set of notes, when a new mark, or a record point, appears several times, the subsequent references do not need to include a complete description, but the reference should be made to the location of the description in the set of notes. For example: "See abstract, page 12, field book 2."

A "set" point becomes a "record" point only when the notes, or a map that show its setting, have been formally filed. On an extensive or prolonged survey, individual pages or groups of pages of completed notes should be submitted for formal filing. This will enable others to use completed segments of the survey, through the new record points, even though the total survey is not completed.

Pointings, Observations and Measurements

Except for perimeter information and point names, pointings, observations and measurements are the only required field entries for notes. These values represent the heart of the survey. Record each required field value in its proper place.

Explanatory notes, such as unusual weather conditions and problems with equipment, aid in the interpretation and analysis of reliability of portions of a survey.

The term "zenith angle" should be used to indicate the measurement process used to measure vertical angles observed with theodolites and total stations.

Those entries which are recorded at the time observations are made are "original" entries. Record original entries of observations. Field notes with original entries have more authority and will be viewed by the courts as such. After-the-fact entries are suspect and more likely to be erroneous.

Notes should not be recopied. However, in those rare cases when notes are copied for clarity, the original notes must be retained. The originals should be attached to the copied notes.

Problems can arise in recording certain types of observations or in interpreting what has been recorded for any type of observation. Some guidelines to follow are:

- Record accuracies that are equivalent to the precision of the equipment and/or surveying techniques.

- Always record the full raw value, as called out, be it from a chainperson or an instrument operator.
- Do not record only the sums or the differences, or the means of a series of raw values. Also, do not record only "corrected" sums, differences, or means. Record "ground" distance, not "grid" or "sea-level" distances.
- Sea-level and grid distances are calculated values. When setting points, show calculations that convert a grid value to a ground value.
- Record significant figures only.
- Clearly indicate the decimal portion of a measured value.
- When different distances or the same distances are measured by more than one method, note the equipment or method used for each measurement.
- Do not erase any observation. If a mistake is made in recording, or if an observation is rejected, draw a line through the entry, without destroying the legibility. Erasures diminish, and often destroy, the credibility of field notes.

Descriptions

A survey point description is a recording (written, sketched, or written and sketched) of the general and exact horizontal (and vertical) location, the datum, and the particular physical characteristics of a point which enable its recovery and the differentiation of that point from any other point.

Importance

The recoverability and positive identification are often in direct relation to the effort expended in originally describing the point. The record points that control a survey must be verified in the notes by descriptions that do their utmost to substantiate the acceptability of the points. Otherwise, the survey could be based on erroneous monuments.

Practice

Do not depend on second hand information such as a chainperson's notes or verbal description. Write the description while at the point.

When record points are not recovered, describe how intense the search was and the area covered in the search. Record any physical evidence found of "obliterated" or "lost" monuments or related changes in topography which might have destroyed a monument and any evidence to it. Describe any physical evidence that might indicate the location of the point that could not be found.

Elements

There are several basic elements that, when included in the description, will aid in its identification in the record:

- Name of the point such as station, control number, USGS number or name, section, township, range, etc.
- Origin of monument (found or set).
- Size and materials (stone 14 inches x 24 inches, 2-inch ID pipe, etc.).
- Position relative to surface (12 inches under county road surface, etc.).

- Condition.
- Specific marks (stamping, scribing, etc.).
- General location and calls (hillside, west of Rte. 120, 20 feet from S. river bank, etc.).
- Document or field notes that first described point.

Delineation

Delineation is the act of drawing lines, symbols, numerals and letters on field note sketches to aid in interpretation and understanding of the notes by others.

Delineation

Some basic but extremely important rules to follow when delineating field notes are:

- Use standard form when available.
- All field notes should be recorded on standard field notebook paper which is available by requisition from the district office.
- Do not try to economize on paper.
- Work at a speed that is within your ability. If data is relayed to you faster than you can record, either slow down the survey or give way to a faster recorder.
- Do not crowd information to a point where numbers or letters are hard to distinguish or some information is covered.
- Make notes dark enough to be reproducible. Notes should be written with a 3H or 4H pencil or equal. When the lead is too hard the notes are difficult to read and do not microfilm well. When the lead is too soft, the marks tend to smear.
- Use standard abbreviations and symbols — see Appendix C for standard abbreviations.
- Use drafting aids.
- Be consistent in style and lettering.
- Field notes are made by many individuals who use different methods of forming numbers and figures. The essential requirement is that notes be legible and descriptive. Notes should be recorded so that other surveyors may readily interpret any part.

Drawing Sketch Notes

When drawing sketch notes, follow these additional suggestions:

- Draw sketches in correct relationship.
- Orient sketches and entries according to standard mapping procedure — that is, have everything read from the bottom or right edge of the sheet.
- Draw the framework of the sketch before measurements begin.
- Do not waste space or time drawing oversize or elaborate north arrows or dimension arrows.

Construction Surveys

The staking books document the location, dimensions, and materials incorporated in the facility. The notes should include all information required for that documentation. Neat sketches are often a great aid for those who have to read the notes and compute pay item quantities. Although the sketches may not be drawn to the exact scale, they should show actual field measurements.

Many methods are available to accomplish the surveying and staking work. It is the responsibility of the field project manager in charge of the construction survey and staking to be familiar with the current computer programs that are available and instructions pertaining thereto.

The construction survey notes cover alignment, bench marks, cross sections, grade stakes, slope stakes, stakes for structures and miscellaneous construction survey data. Survey entries should be the original entry. They are ***not*** to be taken on scratch paper for copying at a later date. All notes shall show the name of the person making the notes, the person doing the checking, the date for each day, the party personnel, and weather information. Symbols may be used to designate the person running the instrument, chaining, rodding or other survey duties.

Each notebook should be identified on the front cover by subject (alignment, cross sections, etc.), project number, control number and the name of the field project manager. On small projects, some separate operations and miscellaneous survey notes may be combined in a single notebook, whereas separate notebooks for each operation may be required on larger projects. Notebooks that contain many different types of survey data should contain an index in the front of the book.

Field books should contain complete information of the constructed centerline or other lines run, reference control points, any errors found in angles or distances, and the corrections made.

Horizontal Control — Centerline

Prior to entering the basic information in the alignment book, computer output information should be checked against the design plans and any discrepancies resolved.

When a centerline or an offset line is used, an alignment book will be required. The alignment book should show all main control points for the project, both random and direct, all other control points, and all occupied station points.

Normally, line sketches of the alignment, offset line and relative position of control points would be shown on the right-hand page. The stationing should start at the bottom of the page and proceed upward. Each occupied station should be shown, as well as the measured distance and azimuth between such points. It is less congested if only one curve and tangents to and from that curve are shown per page. It is generally most convenient also to include curve data on the right-hand page, leaving the left-hand page clear for actual staking notes. Staking notes for the alignment shown on the sketch should be carried on the left page. Such notes would reflect either the traverse stations and deflections, or azimuth and distance to staked station points from control points.

Cross-Section Notes

All recommended practices are aimed at electronic computation of earthwork quantities while maintaining the simplest records possible. The systems and samples conveyed by this manual have been prepared especially for adaptation to electronic computer operations. However, if all "00s" and intersections of template and groundline are caught and recorded, areas can still be computed directly from the notes. Therefore, it is essential that all construction personnel follow the prescribed patterns

as clearly and uniformly as possible. Cross-section notes and data are to be entered and recorded on Form CSN-01. An explanation set of notes is shown in Figure A-35.

Every set of cross-section data that is submitted from the field should be thoroughly and completely edited by the field project manager, instrument operator or office person who is responsible for the final accuracy of the notes. Additions or changes are identified by placing cards in the appropriate position in the set of notes and are further identified in colored pencil. If changes are of a nature allowing correction by Construction Bureau personnel, the calculations will be completed. If the errors cannot be corrected in Helena, the notes will be returned to the field for corrections or clarification.

Borrow pit cross-section notes are similar to other survey notes in that the data, weather information, and members of the crew are to be recorded for each day. These notes should be neat and well kept. Figures that are in error should be crossed out and the correct figure written above. Do not erase.

Major Structures

Separate field books should be set up for each major structure and maintained on a daily basis when work is being done on the structure. Information for setting up staking diagrams and sketches should be obtained from the detail sheets in the plans. Separate pages should be used to show the overall staking system and detail drawings of the various structural components. Do not try to crowd too much information on one page.

Minor Structures

Staking books are generally set up in the office from the plans as amended by the revised pipe list. Sufficient pages should be reserved in the book for all notes that would be required for each separate installation.

Common Errors in Notekeeping

Construction notekeeping errors that occur fairly frequently are discussed in this section.

Plus and Minus Rods

A minus rod reading represents an elevation below the height of instrument (HI). A plus rod denotes ground or templates higher that the HI. Plus rod readings are preceded with a plus sign (+).

Normally, it is assumed that if there is no sign in front of a rod reading it is a minus rod. One exception is illustrated by the following example, where there were a series of plus readings with one or two in between without signs.

+5.6	+4.1	+3.6	+2.8	1.2	1.4	+2.3	+3.2
19	25	28	30	33	35	38	41

It is not clear whether the readings at 33 and 35 are actually minus readings or if the notekeeper forgot the + sign. In such a case if the readings are actually minus readings, it is suggested that they be written as: $\frac{-1.2}{33}$ $\frac{-1.4}{35}$

Distance Out of Sequence

Occasionally a distance reading is out of proper sequence, such as 00, 10, 15, 25, 20, 31, 36. Are the readings at 25 and 20 reversed? Should the 20 be 28 or 30? Is there a cave or overhang? If the readings are true, explain. Be sure to edit the notes for such occurrences.

Catch Point Not Defined

Occasionally, the catch points, particularly the outside fill or cut, are not clearly defined or readily discernible. It is imperative that all note recorders use a standard practice in the case of outside catches. See the sketch and Paragraph R in Figure A-36. Leave at least one blank space each side of the outside catch; enter the amount of the cut or fill above the rod reading.

Excavation Without Centerline

Occasionally, a borrow area is cross sectioned without a centerline or baseline. This usually occurs as an extension of roadway sections off the roadway centerline. It is essential that every set of cross sections has a centerline or baseline. See Figure A-38.

Wrong HI

Sometimes the notekeeper will, in transposing the HI to the next page, carry forward an incorrect number, such as 3152.69 being carried forward as 4152.69. The error may be carried past a bench mark without being corrected. When data are entered using an erroneous HI, the answers are, of course, incorrect.

HI in Wrong Column

Occasionally a recorder will write the HI, when starting a new page, in some column other than the HI column. This causes errors in elevations and end areas from erroneous data entry.

Decimal Points

Now and then a recorder will forget to enter a decimal point in a rod reading or distance, or will enter a decimal point where there should be none.

Corrections to Notes

Data Processing tabulates all of the cross-section data, both template and groundline, and saves it for future use. On occasion, cross-section notes must be amended, supplemented or otherwise revised after Data Processing has computed the quantities. Remeasure and cross-section extensions are two examples.

Changes to groundline records should be made with red pencil so they are easy to find. If the changes are recorded on completely new sheets, such as for borrow widening, the notes need not be in red, but should be clearly marked and noted that the change is to be considered when computing remeasure quantities.

If groundline notes have been submitted once for original computations, and no changes or additions were made, the notes need not be resubmitted to Helena. If only a few changes were made, it may suffice to send in only the sheets or pages that were modified. The field project manager should send sufficient sheets and explanations so there is no confusion in computing the quantities accurately.

Data Transmittal

When staking and remeasure notes are submitted to Helena for computation of areas, volumes and quantities the package must be addressed to:

Montana Department of Transportation
Construction Bureau
2701 Prospect Avenue
Helena, MT 59620

The package ***must be*** identified on the outside, near the lower left-hand corner, by control number, project number and type of notes.

CN 2710
F 192(7)
Cross-Section Notes

A memorandum of transmittal must be submitted in duplicate, separately from the notes. This memorandum shall contain such information as project and control numbers, type of notes (construction, remeasure, etc.), the coverage, and other pertinent data. The Construction Bureau will send the data to Data Processing. The requested data will be returned to the field project manager as soon as processing is completed. All contact with the Data Processing Bureau will be coordinated through the Construction Bureau.

Disposition and Use of Notes

During the course of a survey, a great deal of existing data sources and newly created survey information is in the care of the survey party. Loss of, or damage to, any of the information can be expensive and cause a considerable loss of time.

Handling

Each party chief should make provisions for proper handling and storage of blank forms, notes in progress, and notes that are newly completed. Clipboards, sun visors, chaining bags, dashboards, and vehicle seats do not qualify as proper storage.

Originals of record notes or those of which there is only one copy should not be sent to the field. Use benchmark summaries, primary control maps, coordinate control maps and listings, and copies of the originals.

Indexing and Checking

Field notes with raw values and original entries should be indexed before any review is made in the field office. The immediate indexing aids in keeping track of the notes during the field office review prior to submission to headquarters, when applicable.

Field office checks, adjustments and reductions should be made before notes are accepted. Examples of checks are mathematical errors, recordation blunders, traverse closures, spirit level and vertical elevation closures, complete point descriptions, and the taking and recordation of proper data needed for the point described. Examples of adjustments would include spirit level and vertical angle elevation runs. The final adjustment of the traverse needs to be done at this time.

Submittal

After review and approval in the field survey office, completed field notes should be promptly submitted to the appropriate section in Helena for processing and distribution of information derived therefrom. The District should photocopy all original field notes prior to mailing the originals. In some cases, original field notes may be retained by Photography & Survey, sent to Road Design, or returned to the field. Photocopies of notes should be retained by the field for continued use while the originals are being processed.

Often, field surveys are transported by incoming traffic to Headquarters. When such procedure would unduly delay the transmittal, survey packages may be mailed. When original field notes must be mailed, they should be sent by registered mail, with a return receipt requested.

Figure 11-1 is a check list. This form is to be completed by the field project manager and included with all preconstruction field notes submitted to Photography and Survey. All "no" answers on the form must be explained. Each field book should contain notes for only one type of survey. For example, the notes for bench levels and cross sections should be in two separate books. This greatly simplifies distribution of the field notes.

Sample Notes

Sample notes are included in Appendix A. A complete listing of the notekeeping samples is on Page A-1.

Figure 11-1
Field Note Check List

FIELD NOTE CHECK LIST
TO BE COMPLETED BY THE FIELD PROJECT MANAGER OR PARTY CHIEF
PRIOR TO SUBMISSION OF FIELD DATA

Control Traverse:	**Yes**	**No**
1. Instrument used: _____		
2. Distance of the longest traverse loop: _____ Miles		
3. Origin of bearing (How & where?): _____		
4. Baseline User Report previously submitted:	____	____
5. Tribrachs adjusted prior to traverse:	____	____
6. Control abstract on disk including location, description, and coordinates of all traverse control points:	____	____
7. Angular error less than maximum allowed in all cases:	____	____
8. Angular error adjusted prior to traverse balance in all cases:	____	____
9. All traverses closed within specifications:	____	____
10. Control traverse diagram:	____	____

Bench Levels:

1. Instrument used: _____		
2. Level "Pegged" prior to bench levels:	____	____
3. All loops closed within specifications:	____	____
4. Error in all bench levels adjusted:	____	____
5. All bench marks described (What and where):	____	____

Other Levels (Includes photo control points, additional bench marks, and control points not used during the bench levels):

1. All loops closed within specifications:	____	____
2. Error in all loops within specifications:	____	____
3. Intermediate foresights were ***not*** used:	____	____
4. All points described (What and where):	____	____

Ties to Property, Property Controlling Corners and 600 Series Photo Control Points:

1. All ties were made by traverse or approved side shot procedures:	____	____
2. All monuments tied are described (e.g., Found or set, size, and markings and/or stampings on cap):	____	____
3. If a side shot, the radial error in all cases was less than or equal to 0.25 foot:	____	____
4. All traverses — the angular error was less than the maximum allowed in all cases:	____	____
5. Angular error adjusted prior to traverse balance in all cases:	____	____
6. All traverses closed within specifications:	____	____
7. All required recordations (Record and new) included:	____	____

Explain all "No" answers on the back of this form.

Signature: _____ Title: _____

Appendix A
Sample Notes

Sample surveying notekeeping formats are presented in this appendix.

Figures

Figure		Page
A-1	Sample Title Page – Bench Levels	A-3
A-2	Peg A Level	A-4
A-3	Bench Levels	A-5
A-4	Differential Levels to Additional Control Points	A-6
A-5	Differential Levels to Photo Control Points	A-7
A-6	Three-Wire Levels – Self-Leveling Level	A-8
A-7	Trig Levels – Automatic Total Station	A-9
A-8	Sample Title Page – Control Traverse	A-10
A-9	Control Point Abstract	A-11
A-10	Control Traverse – Automatic Total Station	A-12
A-11	Control Traverse – Manual Total Station	A-13
A-12	Control Traverse & Tie Angle Point – Automatic Total Station	A-14
A-13	Control Traverse & Tie Angle Point – Manual Total Station	A-15
A-14	Reference Points – Total Station	A-16
A-15	Tie from One Control Point – Automatic Total Station	A-17
A-16	Tie from One Control Point – Manual Total Station	A-18
A-17	Tie from Two Control Points – Automatic Total Station	A-19
A-18	Tie from Two Control Point – Manual Total Station	A-20
A-19	Beginning Traverse to Controlling Property Corner – Automatic Total Station	A-21
A-20	Traverse to Controlling Property Corner – Automatic Total Station	A-22
A-21	Traverse to Controlling Property Corner – Manual Total Station	A-23
A-22	Property Controlling Corner Tie from Control Traverse & P.O.L. – Manual Total Station	A-24
A-23	Side Shots to R/W and PTW – Automatic Total Station	A-25
A-24	Side Shots to R/W and PTW – Manual Total Station	A-26
A-25	Radial Topography from a Control Point	A-27
A-26	Solar Observation	A-28
A-27	Monument Notes – Sample 1	A-29
A-28	Monument Notes – Sample 2	A-30
A-29	Monument Notes – Sample 3	A-31
A-30	Monument Notes – Sample 4	A-32
A-31	Report on Relocation of Bench Mark	A-33
A-32	Blank Form – Report on Relocation of Bench Mark	A-35

Figures

Figure		Page
A-33	Base Line User Report	A-36
A-34	Blank Form – Base Line User Report	A-37
A-35	Cross Sections using a Base Line	A-38
A-36	Sample Cross-Section Notes	A-39
A-37	Cross-Section Notes for Four-Lane Highway	A-42
A-38	Cross-Section Notes for Borrow Widening	A-43
A-39	Cross-Section Notes for Benching and Pavement Widening	A-44

Figure A-1
Sample Title Page – Bench Levels

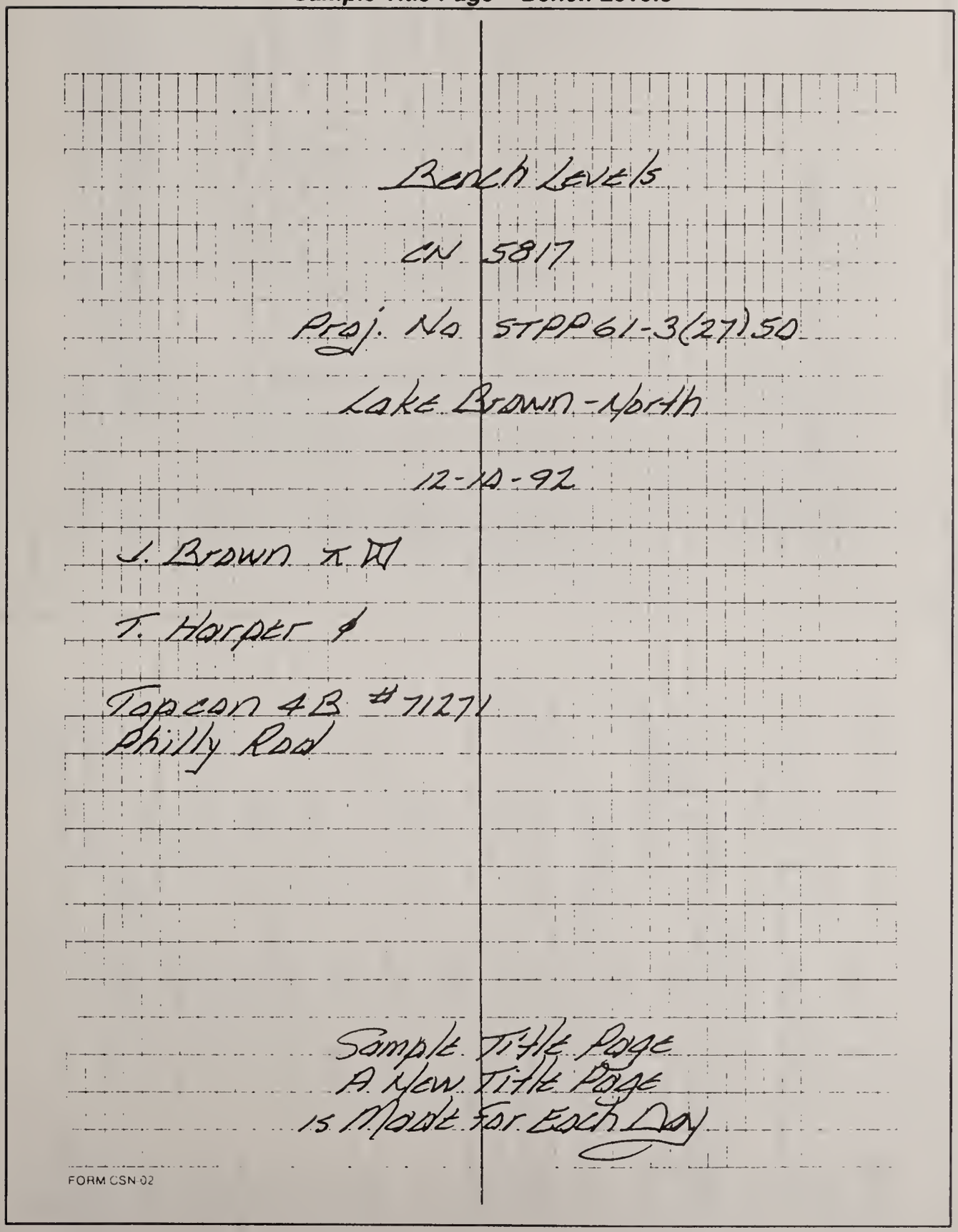


Figure A-2
Peg a Level

Instrument @ mid-point: a = 4.97'
b = 5.72'

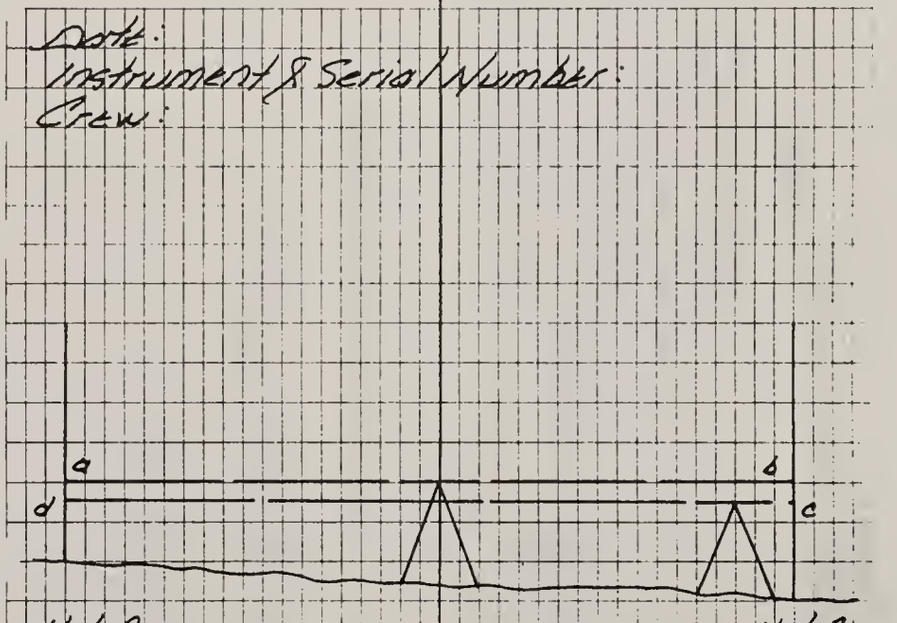
Instrument ± 10' from Hub B:
c = 5.83'
d = 5.02

$d' = d + [(a-b)-(d-c)]$

$d' = 5.02 + (-0.75) - (0.81)$

$d' = 5.08'$

Date:
Instrument & Serial Number:
Crew:



Note: With ± 10' from Hub B cross hairs raised to read 5.08 on rod @ Hub A. See page 8 for readings to check this adjustment.

Sample Notes to Peg a Level

FORM CSN 02

Figure A-3
Bench Levels

Station	BS	HI	FS	Elev	Adj. Elev
D402				3071.18	3071.18
	7.22	3078.40			
TP			9.08	3069.32	
	10.11	3079.43			
129C			1.18	3078.25	3078.25
	7.51	3085.76			
TP			2.83	3082.93	
	10.96	3093.89			
129Z			0.03	3093.86	3093.87
	9.56	3103.42			
603			8.02	3095.40	3095.41
	4.02	3099.42			
TP			6.37	3093.05	
	5.77	3098.82			
TP			4.32	3094.50	
	10.21	3104.71			
129D			9.17	3095.54	3095.56
	8.03	3104.37			
TP			7.36	3097.01	
	5.46	3102.47			
130A			0.19	3102.28	3102.30
	6.37	3108.65			
130Z			1.27	3107.38	3107.40
	8.76	3116.14			
TP			3.14	3113.00	
	1.17	3114.17			
TP			12.82	3101.35	
	5.56	3106.91			
D403			11.87	3095.04	3095.07
	Σ: +101.51		Σ: -77.65		
			+23.86 ✓		

D402 - Standard USC&GS disk found set in concrete ± 78' North sta ± 252+00. NAVD 1988 datum 3071.18

Control Point - See abstract

Control Point - See abstract

Fnd. 5/8" rebar w/ 2" A.C. flush w/ ground. Cap stamped "603 1992" See control traverse notes for location

Control Point - See abstract

Control Point - See abstract

Control Point - See abstract

Error = -0.03

Max Allowable Error = 3 · 0.005 √#FS =
0.015 √ 14 = 0.06

Bench Levels

FORM CSN-02

Figure A-4
Differential Levels to Additional Control Points

Station	BS	HI	FS	Elev	Adj. Elev
29A				3117.52	3117.52
	7.17	3124.69			
TP			8.72	3115.97	
	11.82	3127.79			
29B			1.96	3125.83	3125.83
	8.18	3134.01			
TP			2.97	3131.04	
	10.82	3141.86			
TP			4.53	3137.33	
	5.86	3143.19			
29C			2.02	3141.17	3141.16
	3.17	3144.34			
29Z			10.14	3134.20	3134.19
	5.11	3139.31			
TP			7.82	3131.49	
	2.77	3134.26			
TP			9.42	3124.84	
	5.01	3129.85			
29Y			9.72	3120.13	3120.11
	3.27	3123.40			
TP			9.14	3114.26	
	5.62	3119.88			
TP			6.72	3113.16	
	10.08	3123.24			
29A			5.70	3117.54	3117.52
	Σ = +78.88		Σ = -78.86		
		+0.02 ✓			

Control Point - See abstract

Control Point - See abstract

Control Point - See abstract

Control Point - See abstract

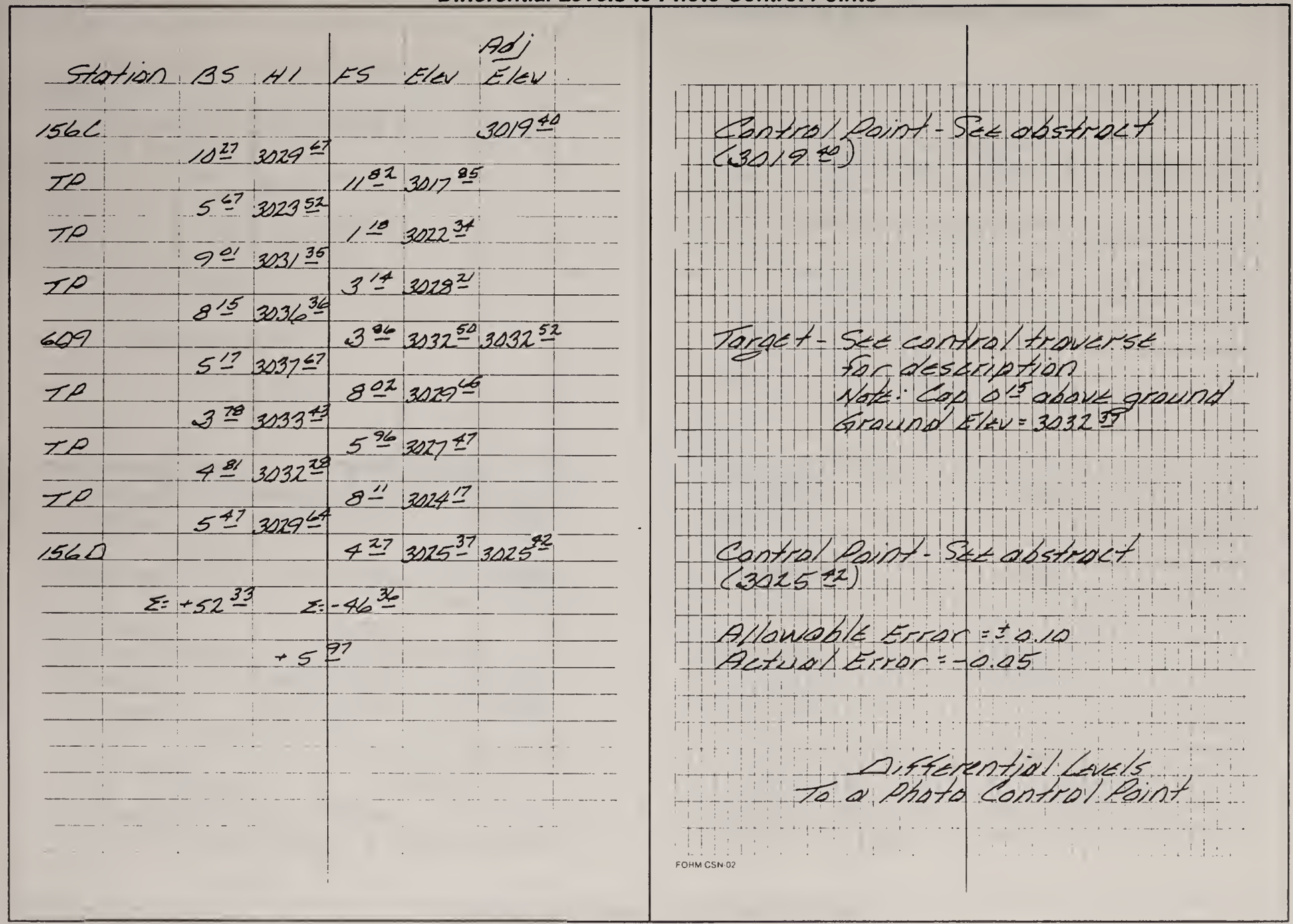
Control Point - See abstract

Allowable Error = ±0.05
Actual Error = +0.02

Differential Levels to Additional Control Points

FORM CSN 02

Figure A-5
Differential Levels to Photo Control Points



Station	BS	HI	FS	Elev	Adj Elev
156C					3019.40
	10.27	3029.67			
TP			11.82	3017.85	
	5.67	3023.52			
TP			1.10	3022.34	
	9.01	3031.35			
TP			3.14	3028.21	
	8.15	3036.36			
609			3.86	3032.50	3032.52
	5.17	3037.67			
TP			8.02	3029.46	
	3.78	3033.43			
TP			5.96	3027.47	
	4.81	3032.28			
TP			8.11	3024.17	
	5.47	3029.64			
156D			4.27	3025.37	3025.32
	Σ: +52.33		Σ: -46.36		
		+5.97			

Control Point - See abstract
(3019.40)

Target - See control traverse
for description
Note: Cap 0.15 above ground
Ground Elev = 3032.35

Control Point - See abstract
(3025.42)

Allowable Error = ±0.10
Actual Error = -0.05

Differential Levels
To a Photo Control Point

FORM CSN-02

Figure A-6
Three-Wire Levels – Self-Leveling Level

BS	Stad	Check	FS	Stad	Check
8.266			3.491		
	0.161			0.171	
8.105		-.0013	3.320		+.0010
	0.165			0.168	
7.940		8.1037	3.152		3.3210
24.311		8.1037	9.963		3.3210
0.326	0.326		0.339	0.339	
6.574			4.623		
	0.216			0.204	
6.358		-.0003	4.419		+.0013
	0.217			0.200	
6.141		6.3577	4.219		4.4203
19.073		6.3577	13.261		4.4203
0.433	0.433		0.404	0.404	
(1)					
	(4)				
(2)		(6)			
	(5)				
(3)		(7)			
(8)		(10)			
(9)	(11)				
		checks			

(4) = (1) - (2), (5) = (2) - (3), (6) = (4 - 5) ÷ 3

(7) = (2) + (6), (8) = (1) + (2) + (3)

9 = (1) - (3), (10) = (8) ÷ 3, (11) = (4) + (5)

(7) must = (10) ± (9) must = (11)

Elev	Sta	Sum
3098.461	BM29	
+8.104		+326
3106.565	HI	
- 3.321		-339
3103.244	TP1	-13
+6.358		+439
3109.602	HI	
- 4.420		-404
3105.182	TP2	+16
		(12)

(12) = Cumulative distances

Note: (4) ± (5) must equal to 0.005 or less
Three Wire Level

FORM CSN-02

Example from K & E Solar Ephemeris, 1974 Edition

Figure A-7
Trig Levels – Automatic Total Station

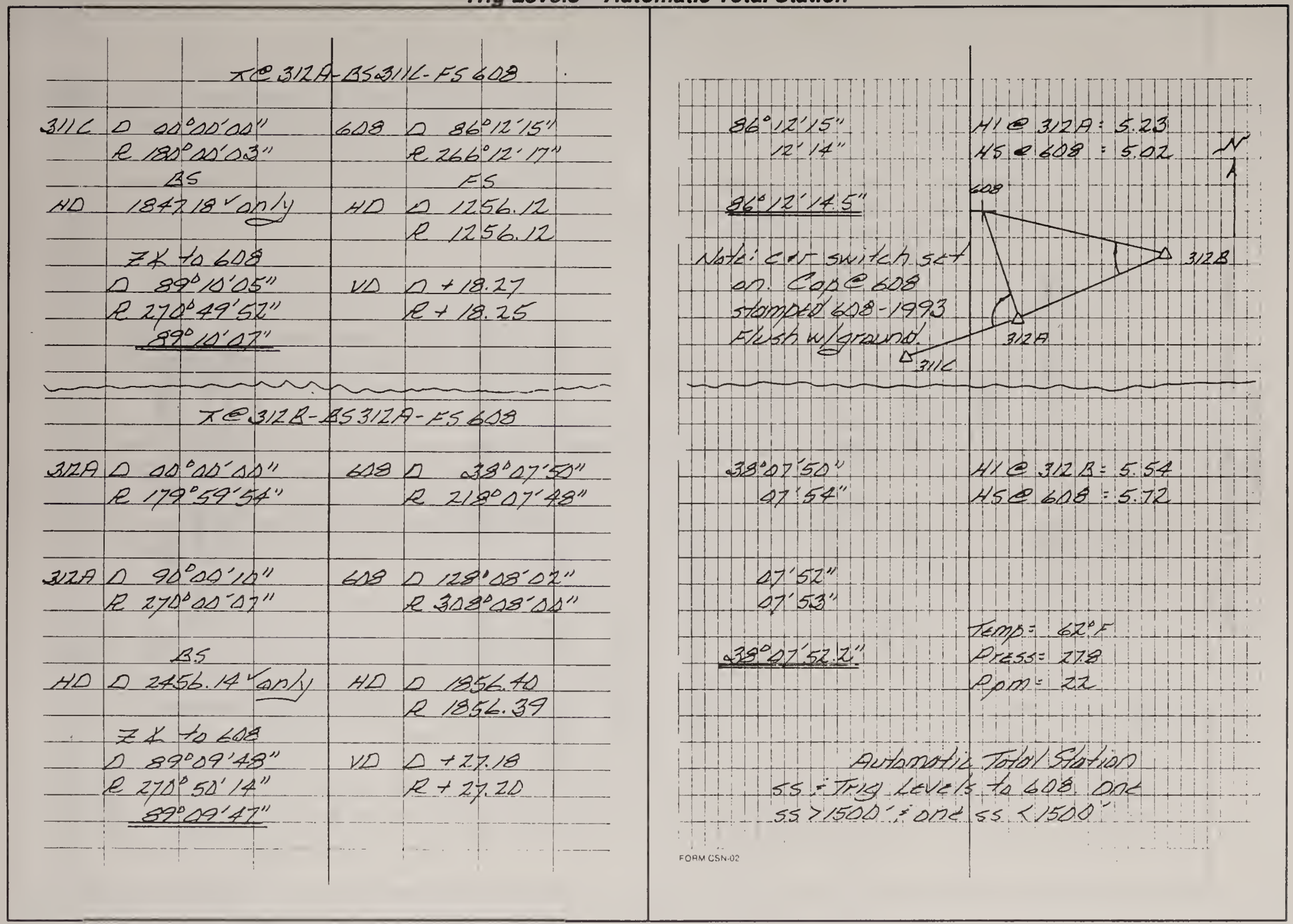


Figure A-8
Sample Title Page – Control Traverse

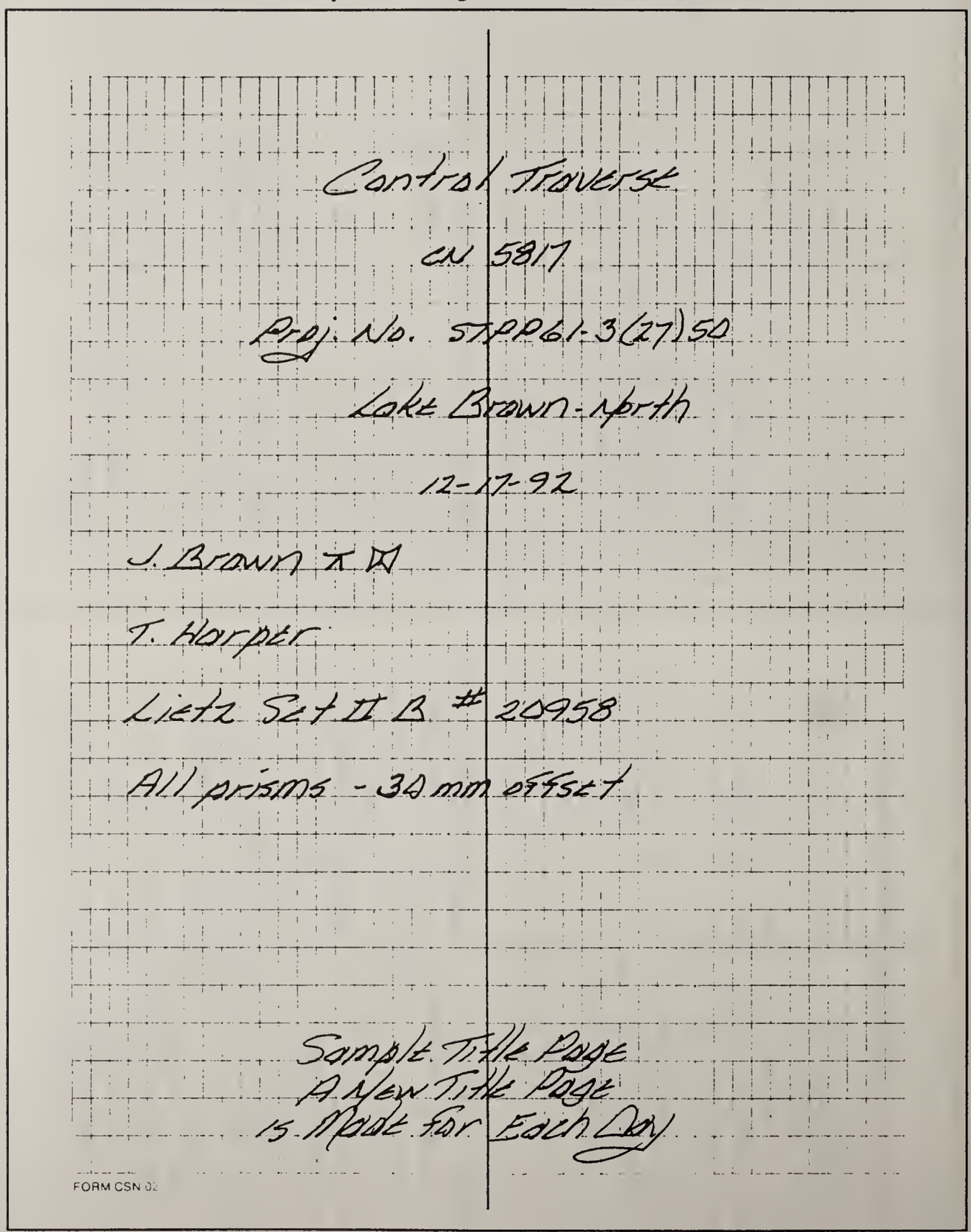


Figure A-9
Control Point Abstract

Control Point Abstract

49Z Set standard control cap (2" A.C.) on a 5/8" x 30" rebar flush w/ ground. Stamped 49Z 1992. Witness post w/decal 2' North. 120' Rt. ℄ @ MP 49.9

49Y Set standard control cap (2" A.C.) on a 5/8" x 30" rebar flush w/ ground. Stamped 49Y 1992 Witness post w/decal 2' North. 135' Rt ℄ @ MP 49.5

49X Found 3¼" A.C. on 3" Aluminum post 4" above ground. Set a witness post 5' East w/decal. 180' Rt of ℄ @ MP 49.2

48Z Set standard control cap (2" A.C.) on a 5/8" x 30" rebar 2" above ground Stamped 48Z 1992. Witness post w/decal 2' South. 80' Rt ℄ @ MP 48.7

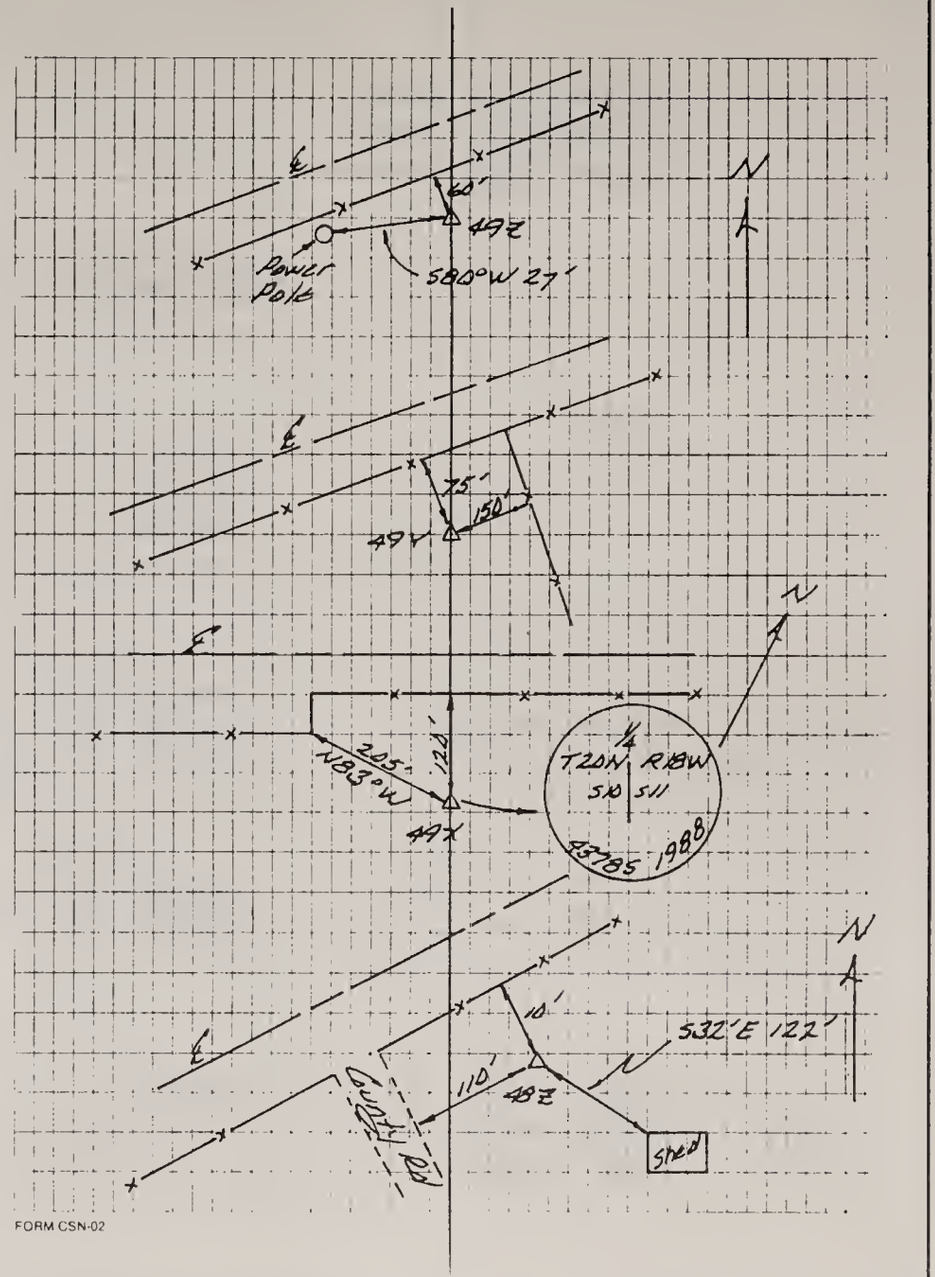


Figure A-10
Control Traverse – Automatic Total Station

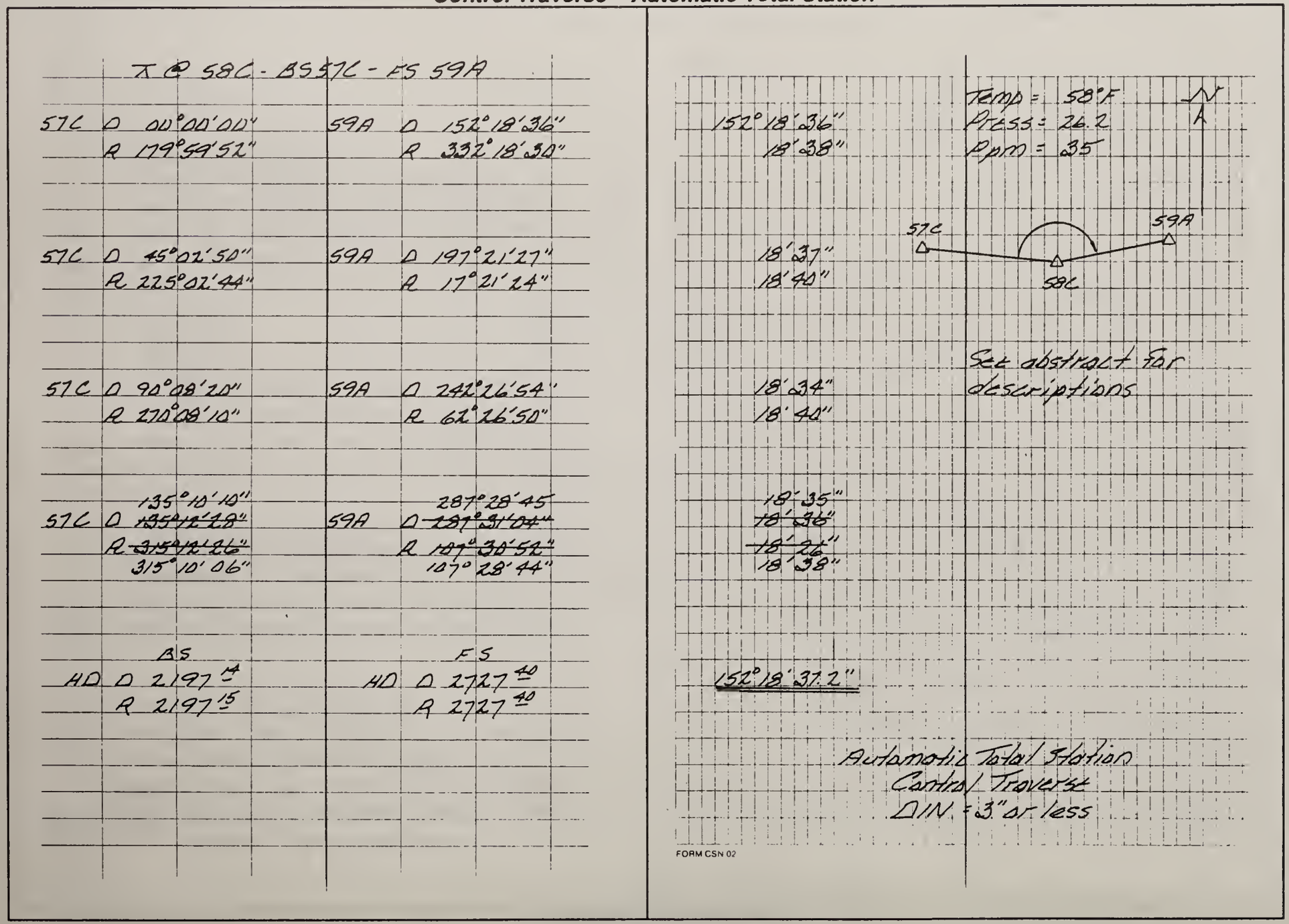


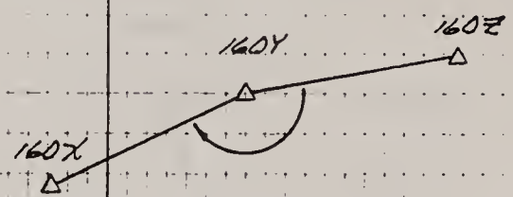
Figure A-11
Control Traverse – Manual Total Station

T @ 160Y - BS | 160Z - FS | 160X

160Z	D 00°00'00"	160X D 197°14'12"
	R 180°00'03"	R 17°14'14"
160Z	D 36°10'40"	160X D 233°24'50"
	R 216°10'40"	R 53°24'52"
160Z	D 72°18'30"	160X D 269°32'44"
	R 252°18'34"	R 89°32'41"
160Z	D 108°42'30"	160X D 305°40'38"
	R 288°42'29"	R 125°40'40"
160Z	D 144°40'11"	160X D 341°54'17"
	R 324°40'06"	R 161°54'16"
	BS	FS
ZX	D 89°10'50"	ZX D 92°02'12"
	R 270°49'00"	R 267°57'40"
	89°10'55"	92°02'16"
SD	2218.82	2602.07

197°14'12"
14'11"
14'10"
14'12"
14'14"
14'07"
14'08"
14'11"
14'06"
14'10"
197°14'10.1"

Temp = 42°F
Press = 27.0
ppm = 19



See abstract for descriptions

Manual Total Station
Control Traverse
DIN = 4" to 6"

FORM CSN 02

Figure A-12
Control Traverse & Tie Angle Point – Automatic Total Station

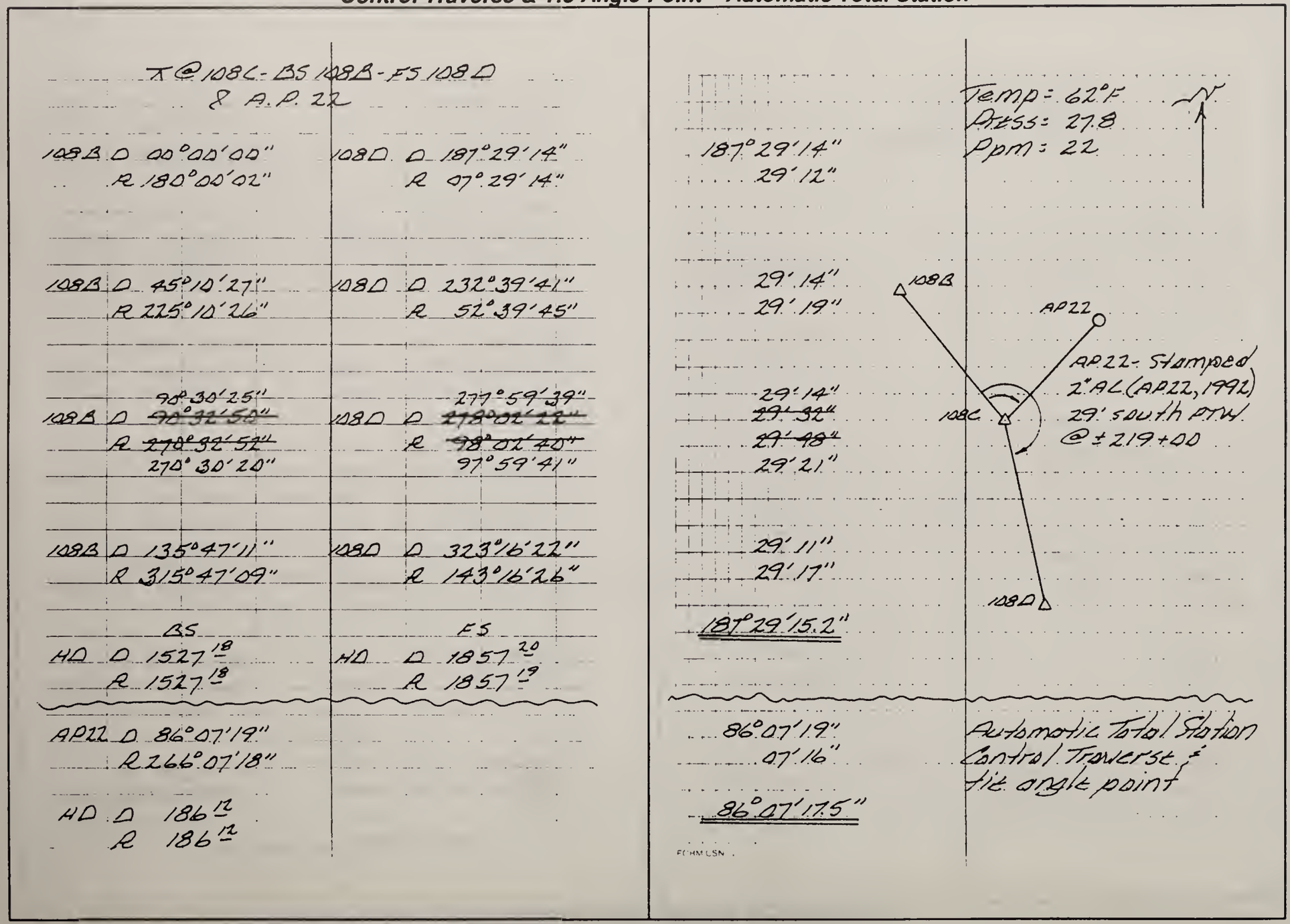


Figure A-13
Control Traverse & Tie Angle Point – Manual Total Station

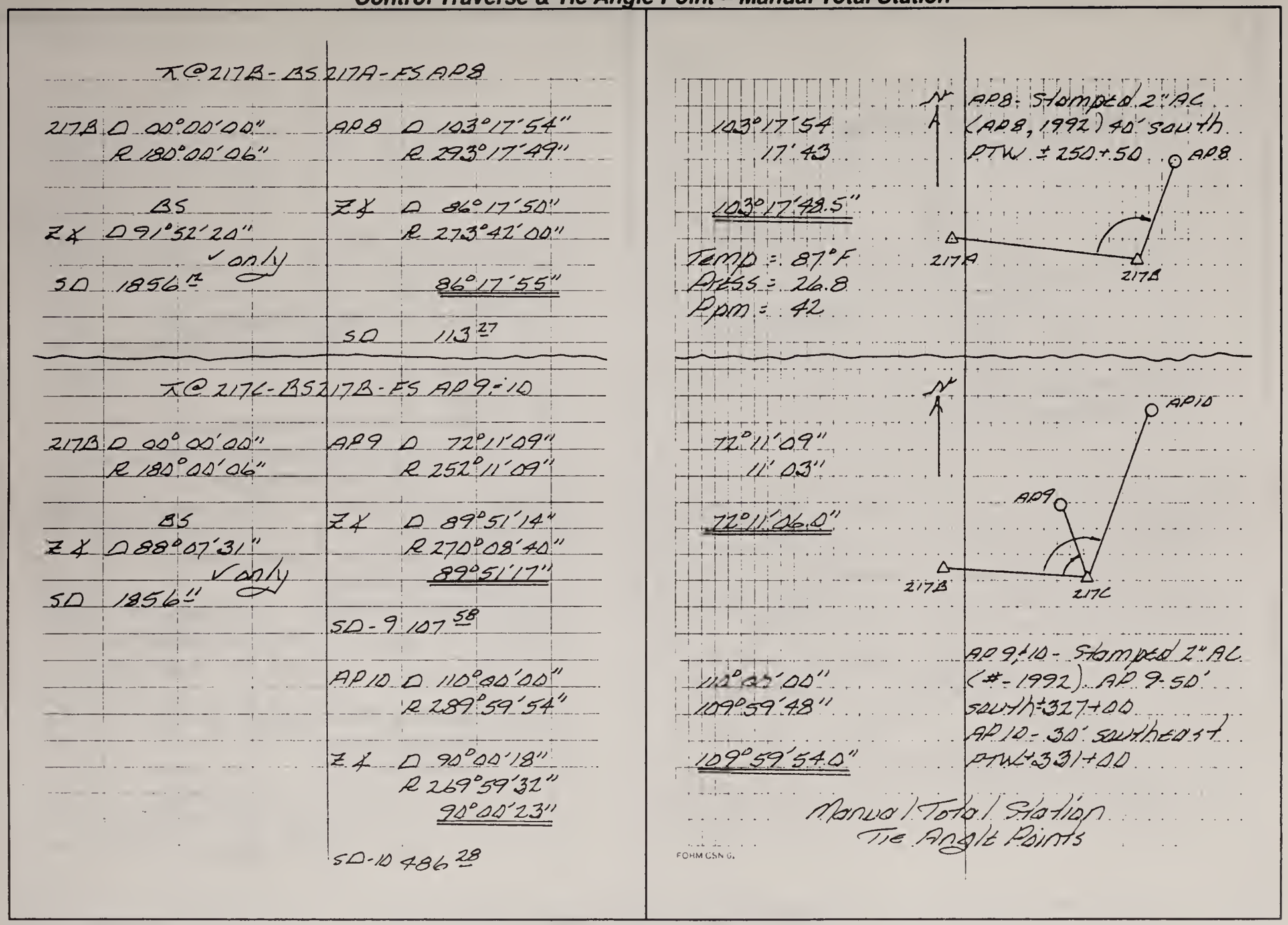


Figure A-14
Reference Points – Total Station

Reference 29C

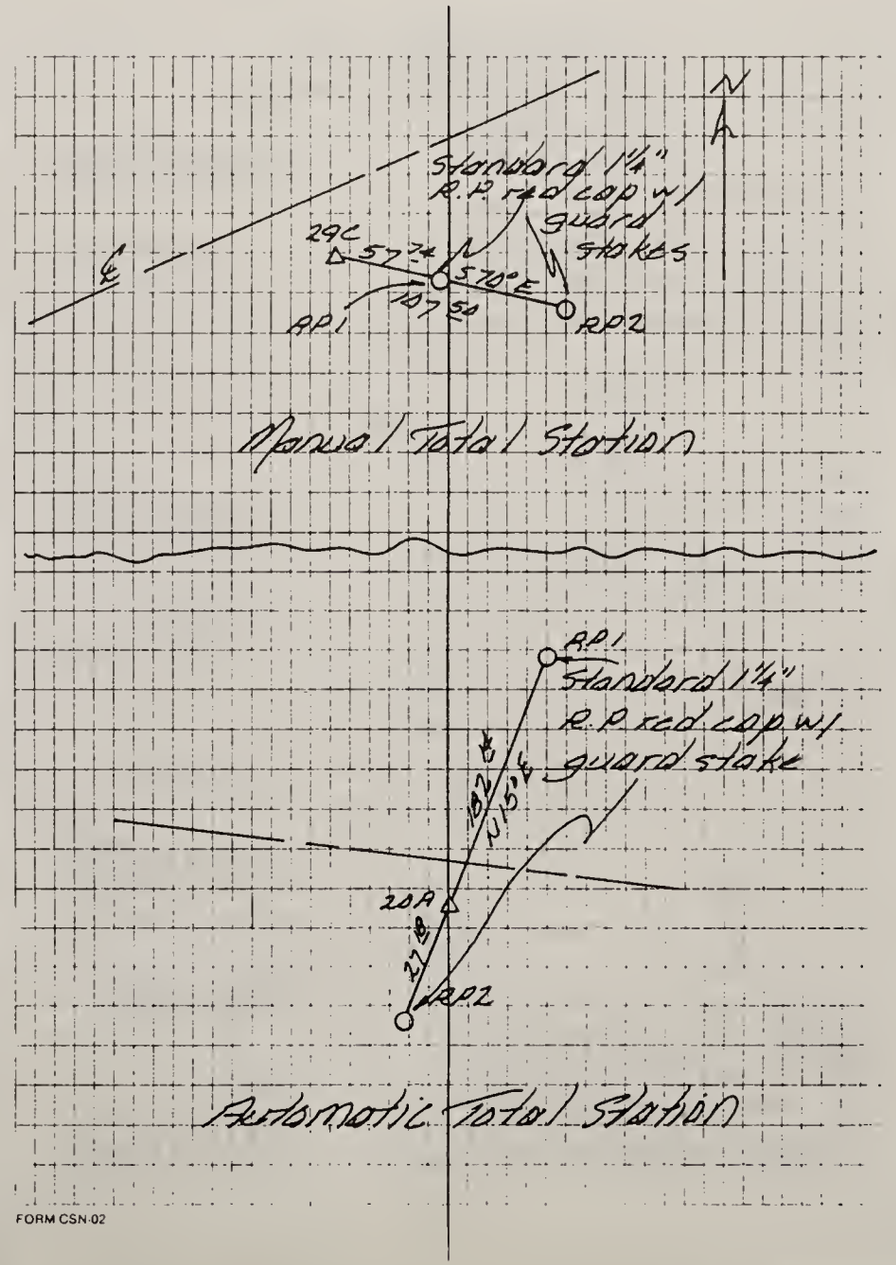
T@29C to RP1
Slope Dist. = 58 27
Zen ∠ = D 82°17'40"
R267°42'00"
X̄ = 82°17'50" HD = 57 24

T@29C to RP2
Slope Dist = 107 47
Zen ∠ = D86°11'28"
R263°48'20"
X̄ = 86°11'34" HD = 107 50

Reference 20A

T@20A to RP1
Horizontal Dist D 182 14
R 182 14

T@20A to RP2
Horizontal Dist D 27 18
R 27 19



FORM CSN-02

Figure A-15
Tie from One Control Point – Automatic Total Station

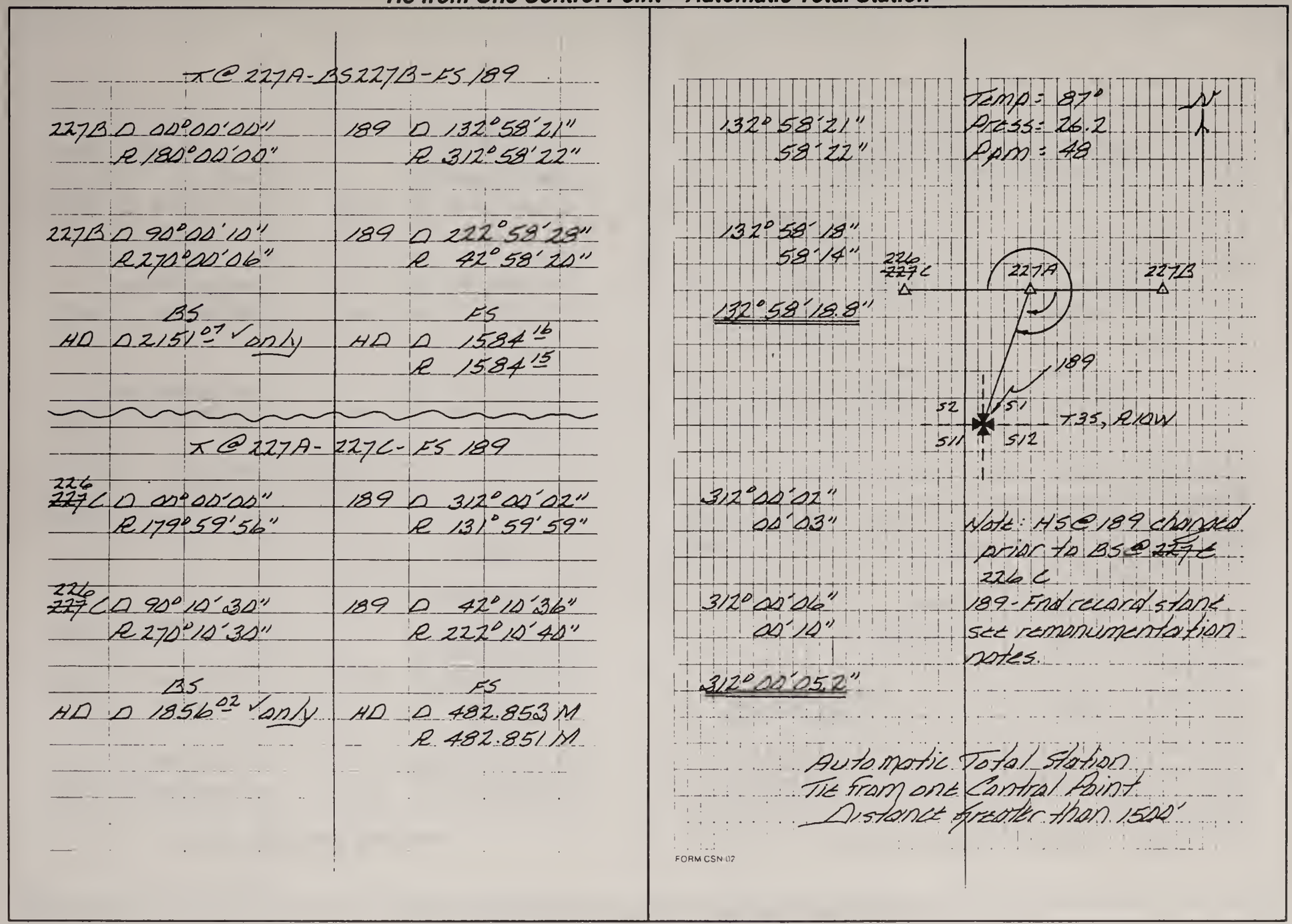


Figure A-16
Tie from One Control Point – Manual Total Station

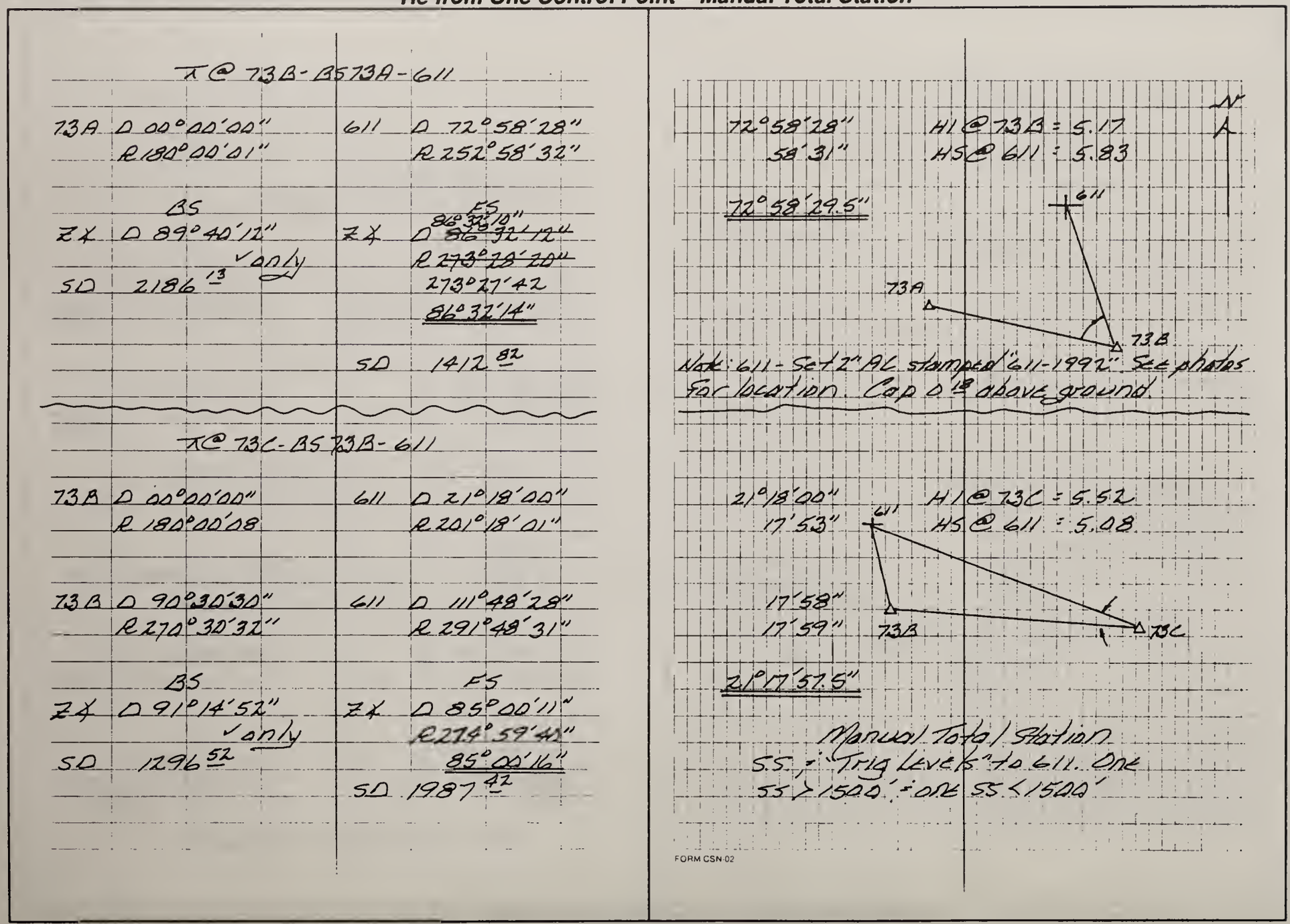


Figure A-17
Tie from Two Control Points – Automatic Total Station

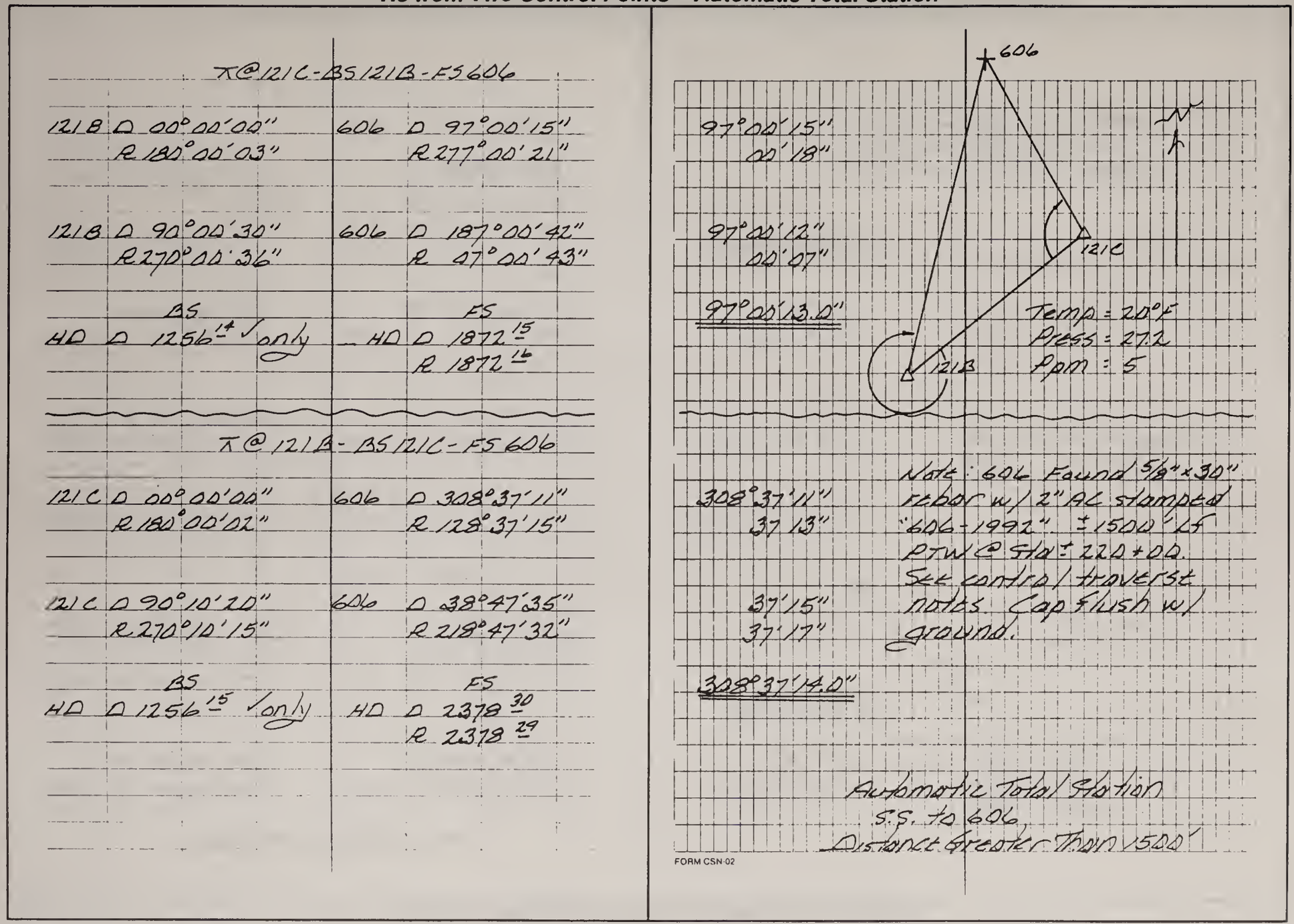


Figure A-18
Tie from Two Control Points – Manual Total Station

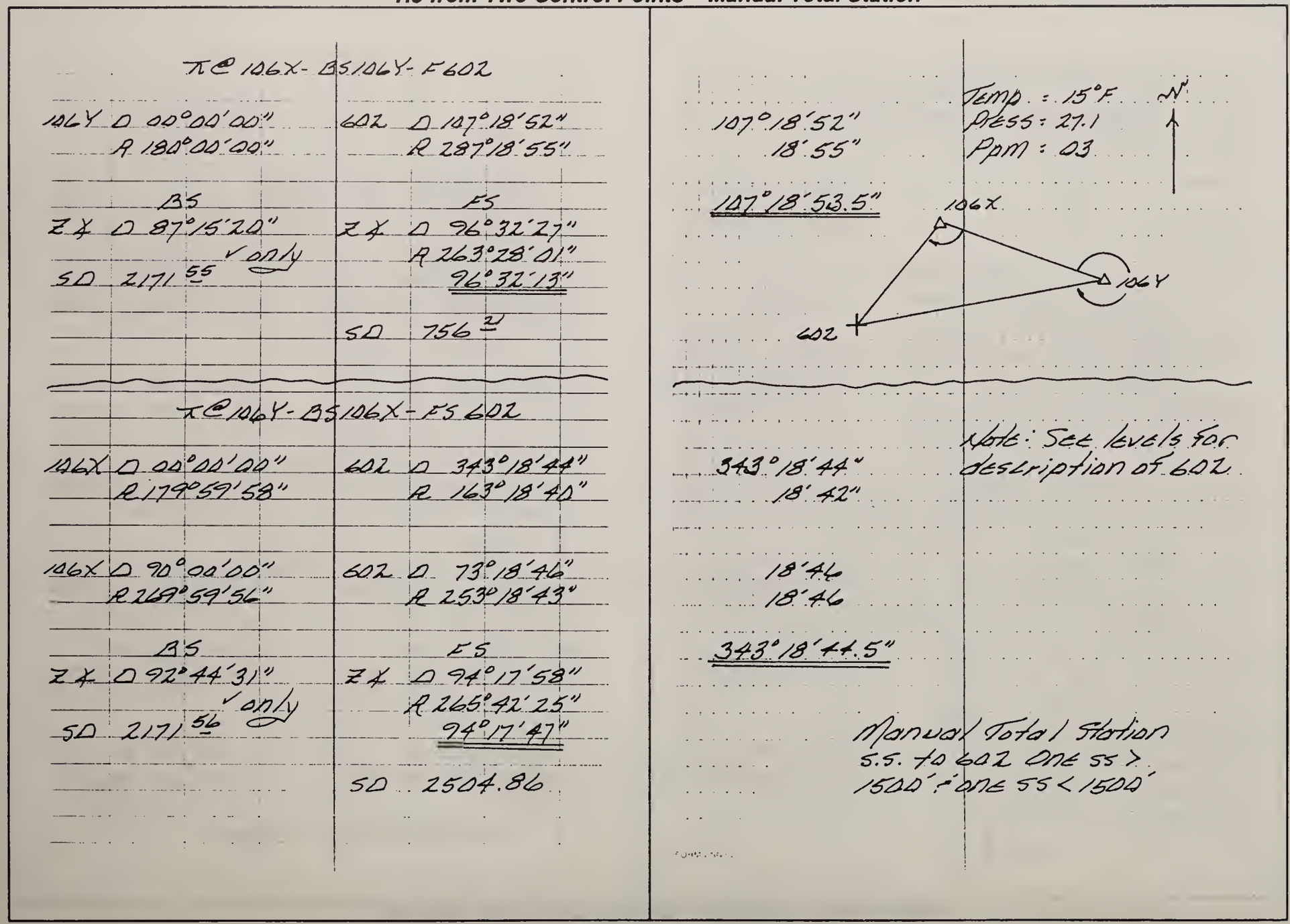


Figure A-19
Beginning a Traverse to a Controlling Property Corner – Automatic Total Station

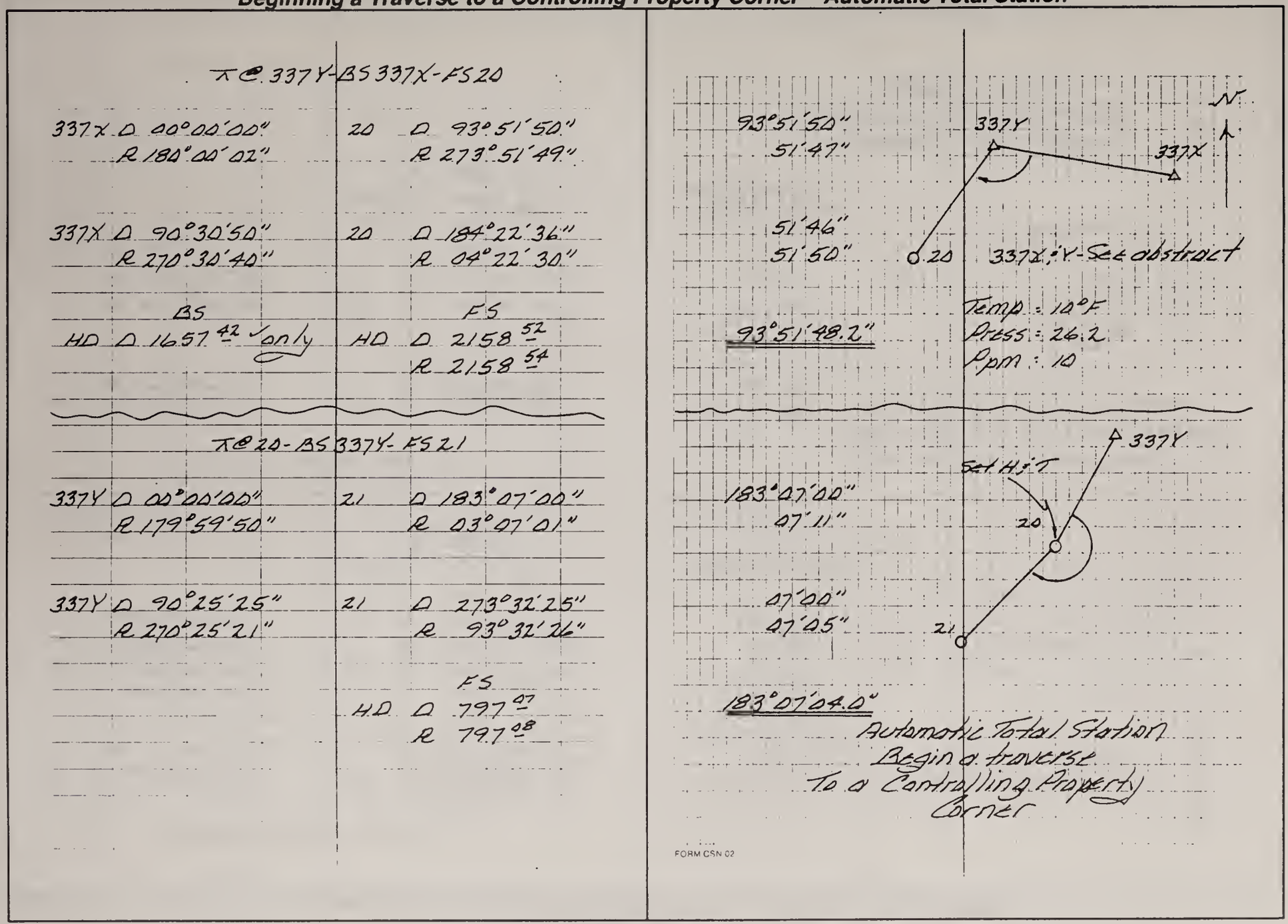


Figure A-20
Traverse to a Controlling Property Corner – Automatic Total Station

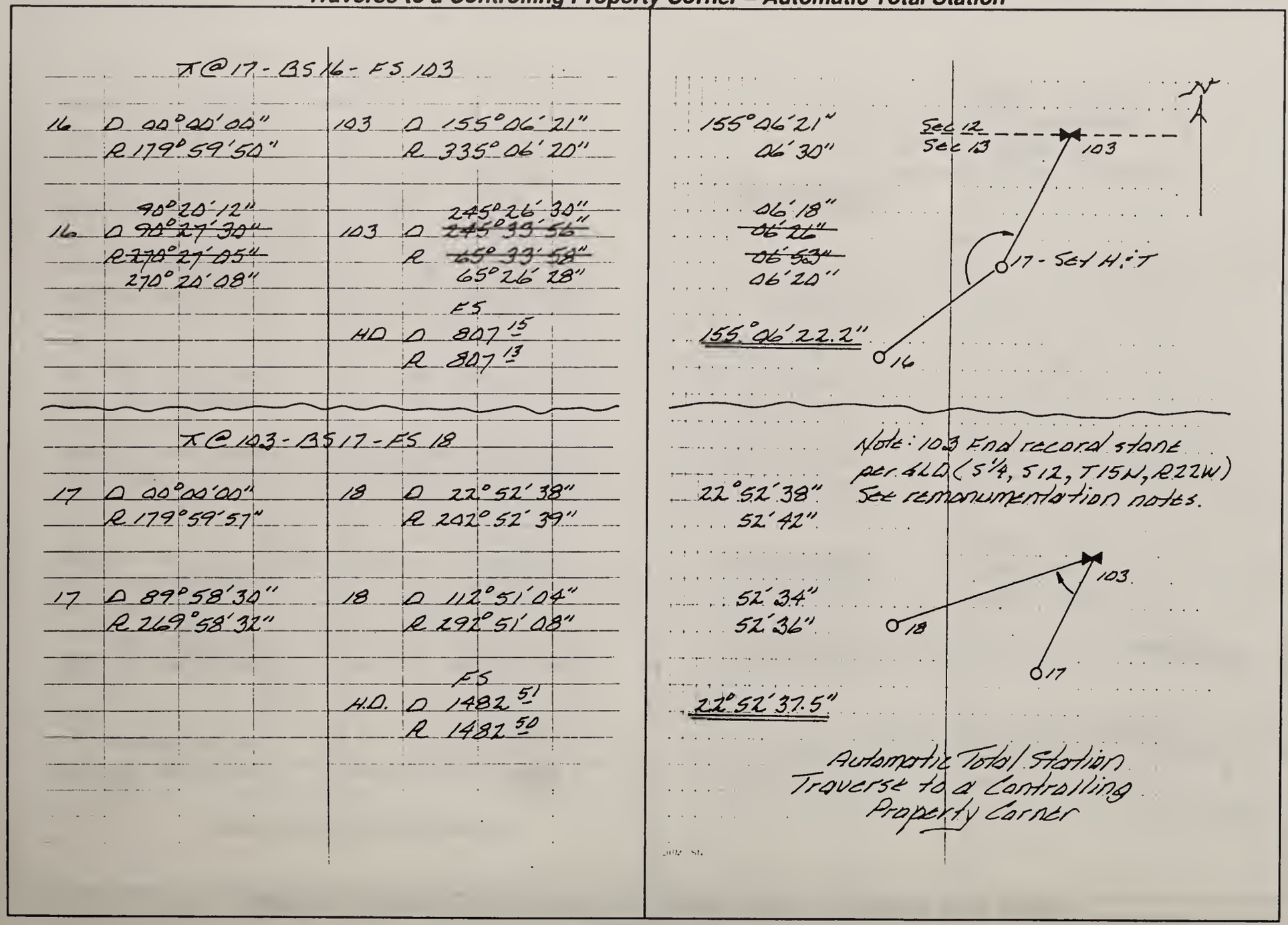


Figure A-21
Traverse to a Controlling Property Corner – Manual Total Station

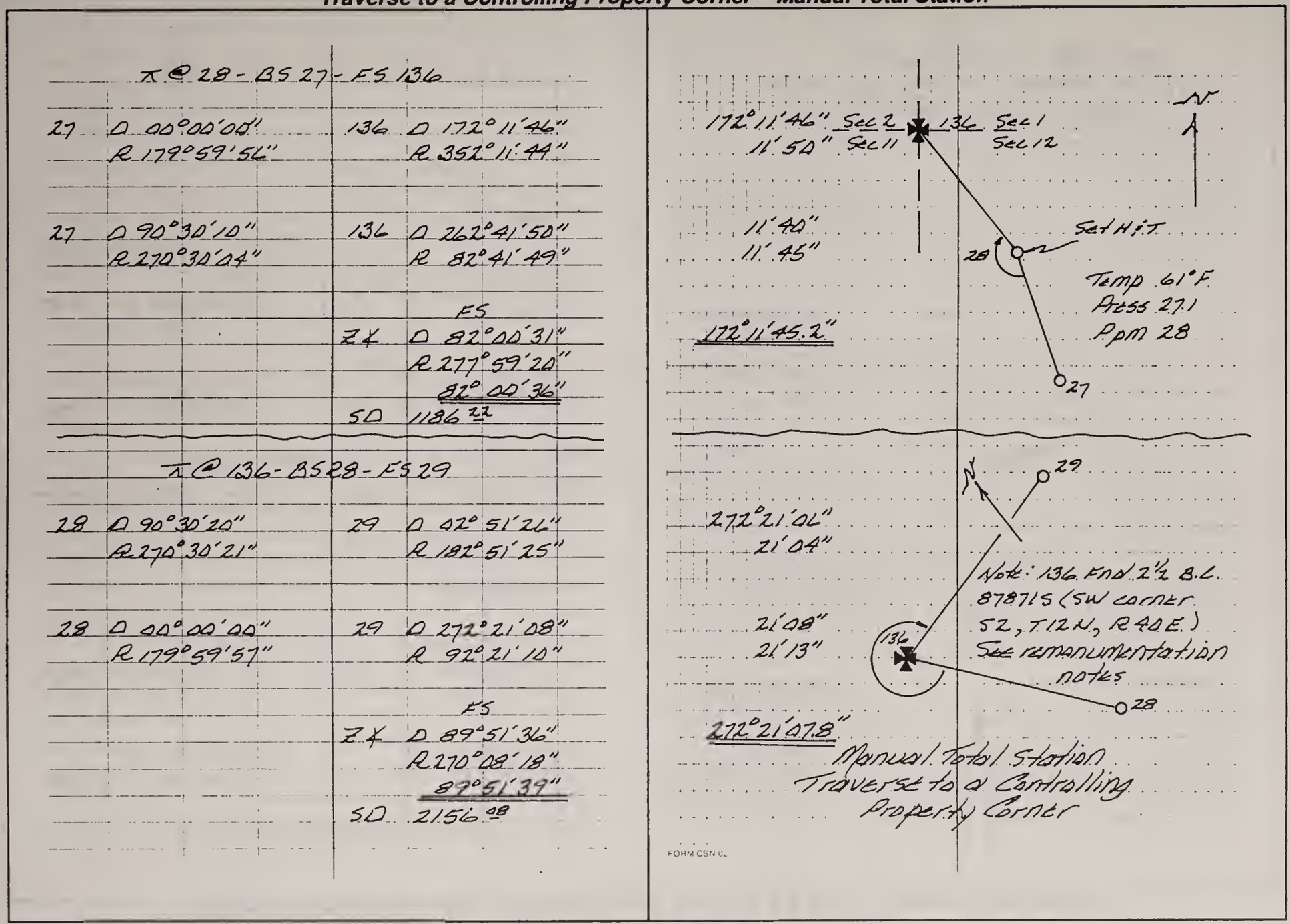


Figure A-22
Property Controlling Corner Tie from Control Traverse & a P.O.L. – Manual Total Station

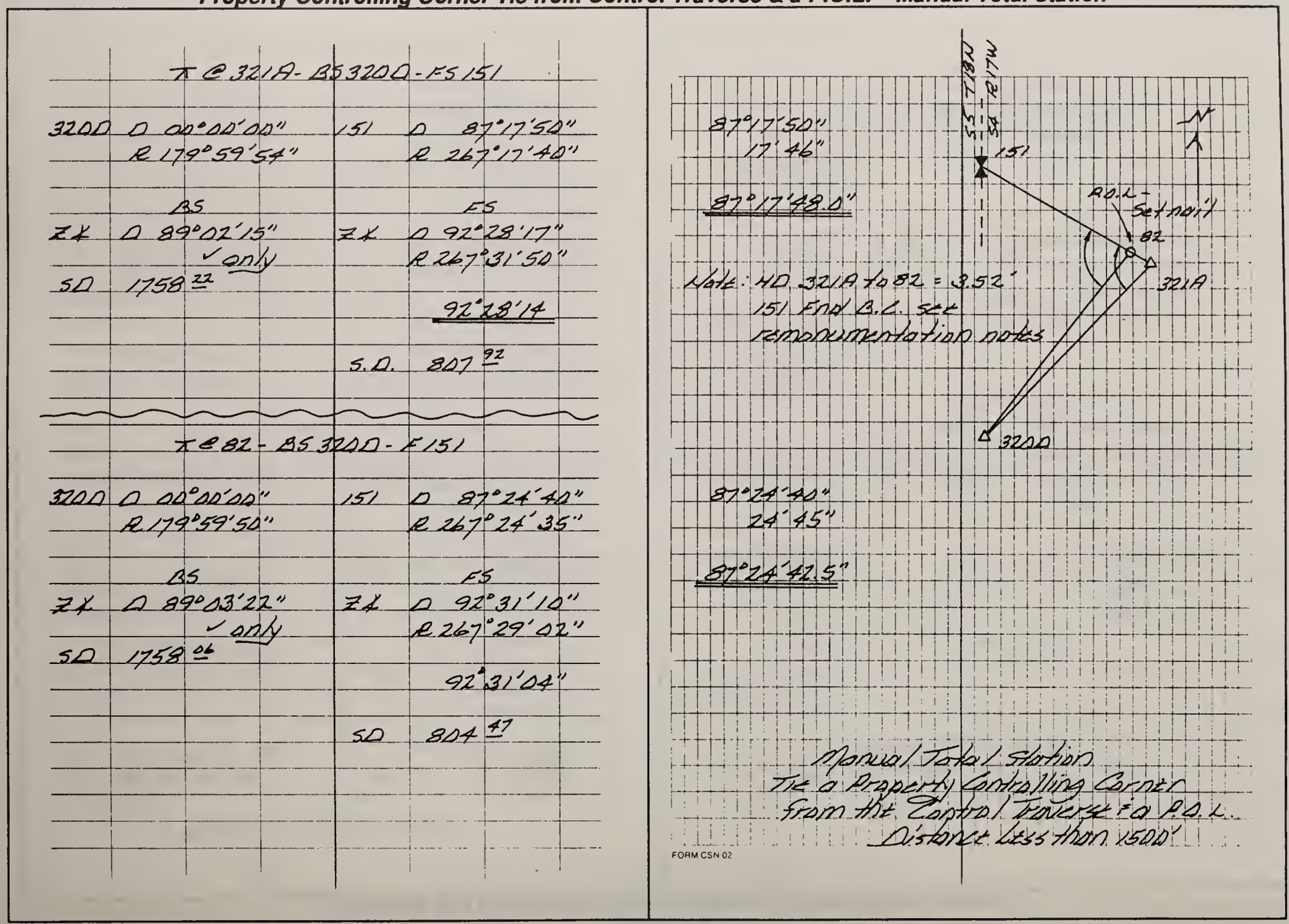


Figure A-23
Side Shots to R/W and PTW – Automatic Total Station

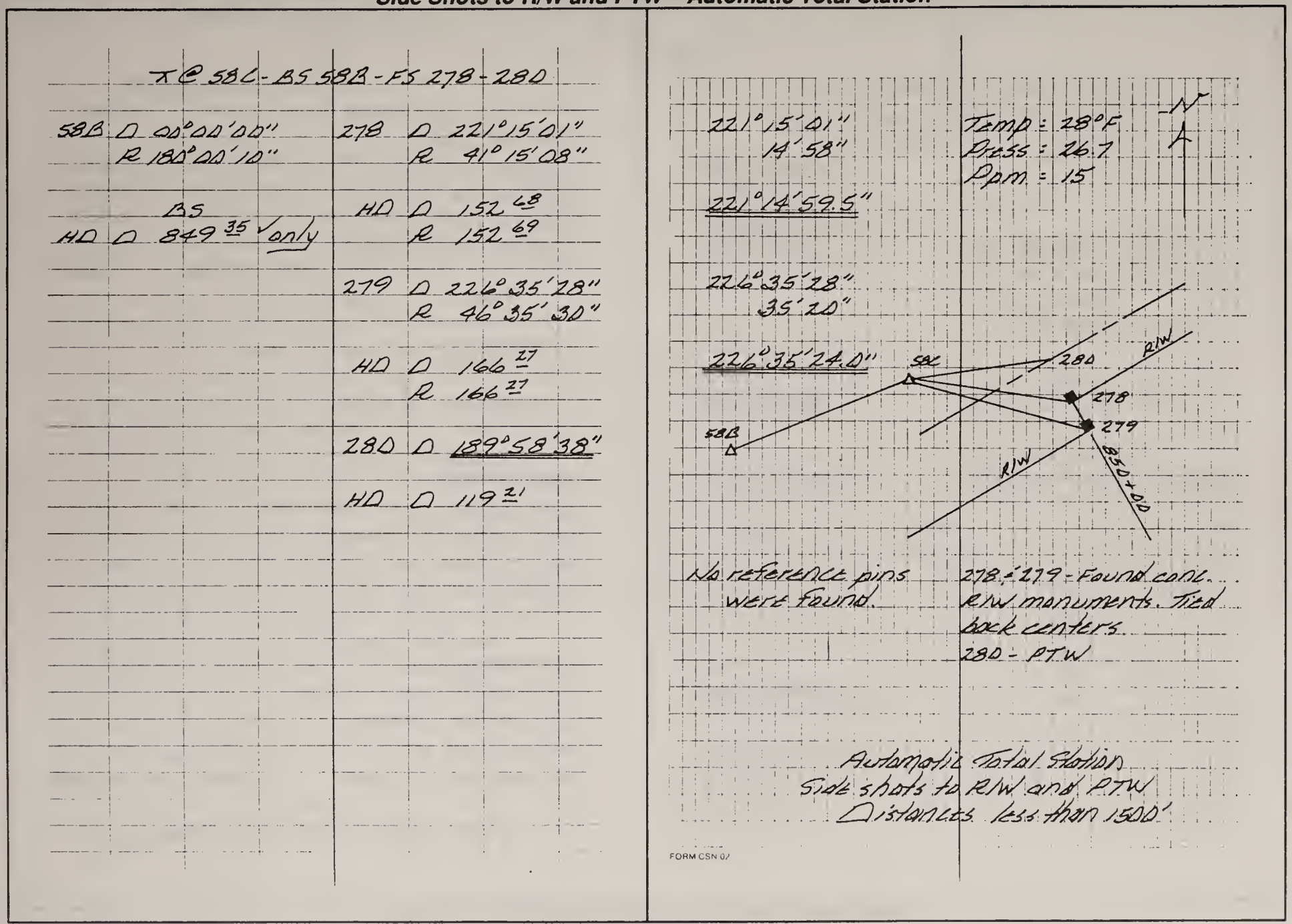


Figure A-24
Side Shots to R/W and PTW – Manual Total Station

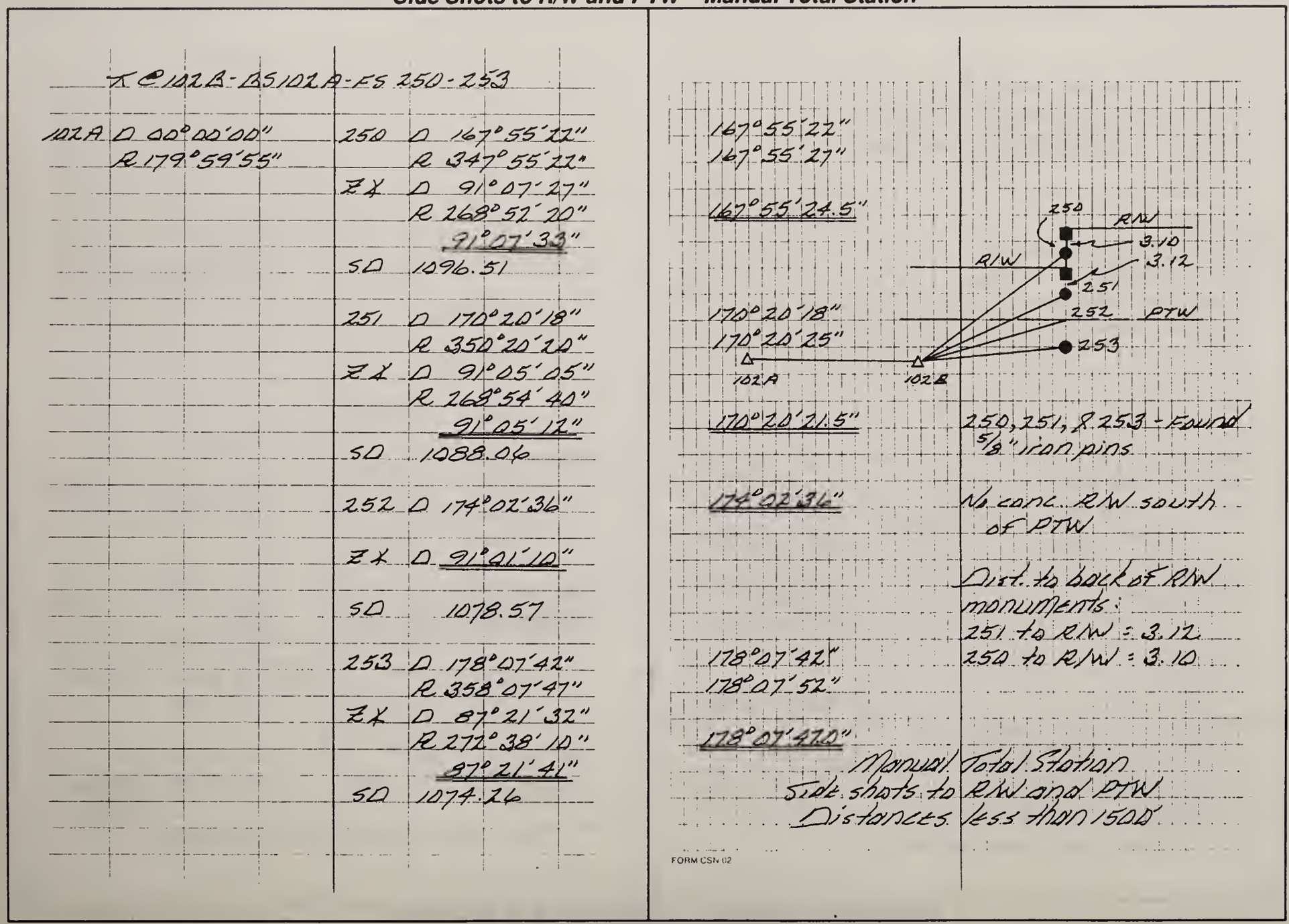
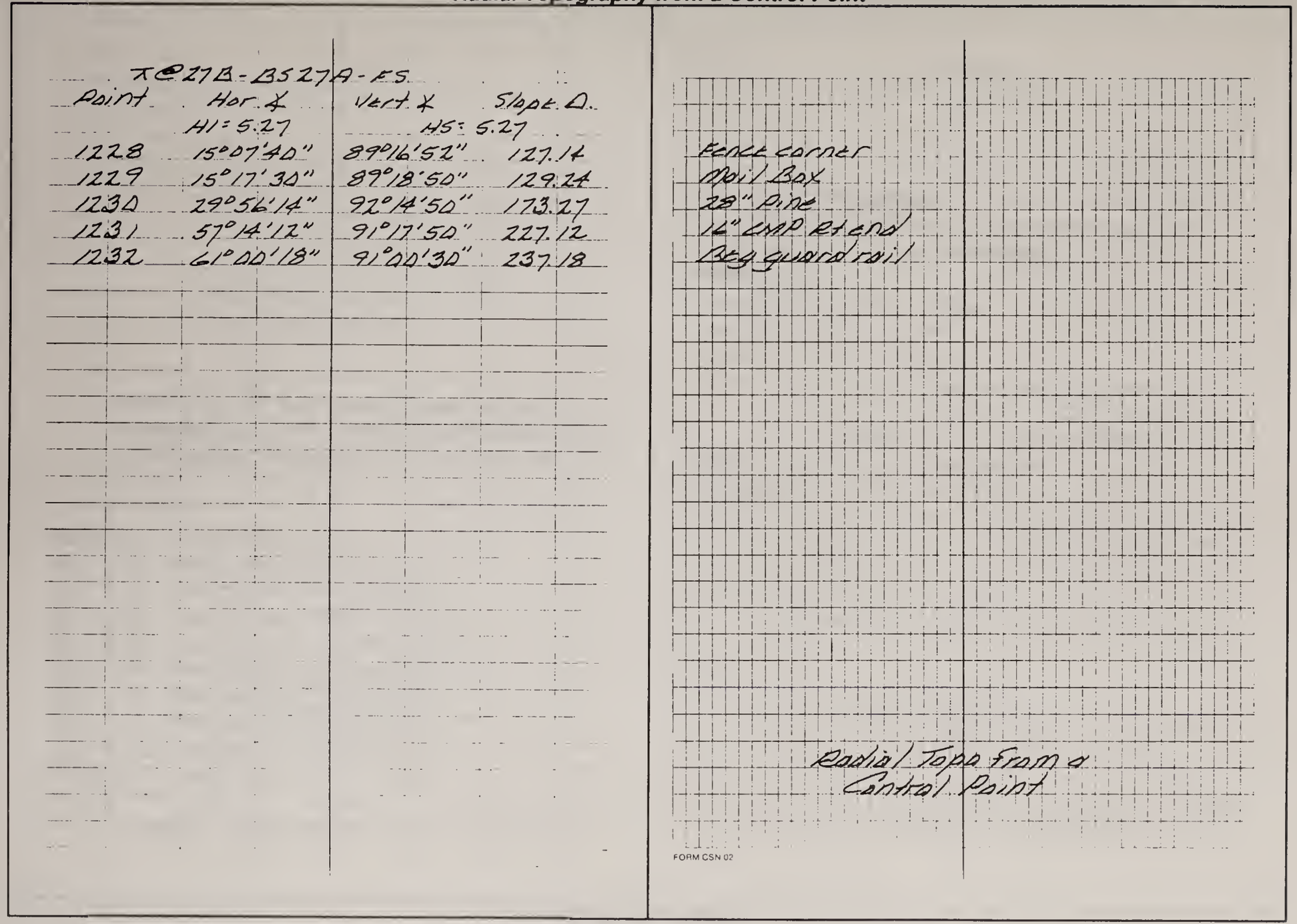


Figure A-25
Radial Topography from a Control Point



TC27B-BS27A-ES

Point	Hor ∠ HI = 5.27	Vert ∠ HS = 5.27	Slope D.
1228	15°07'40"	89°16'52"	127.14
1229	15°17'30"	89°18'50"	129.24
1230	29°56'14"	92°14'50"	173.27
1231	57°14'12"	91°17'50"	227.12
1232	61°00'18"	91°00'30"	237.18

Fence corner
Mail Box
28" Pine
12" CMP Extend
Beg guard rail

Radial Topo From a
Control Point

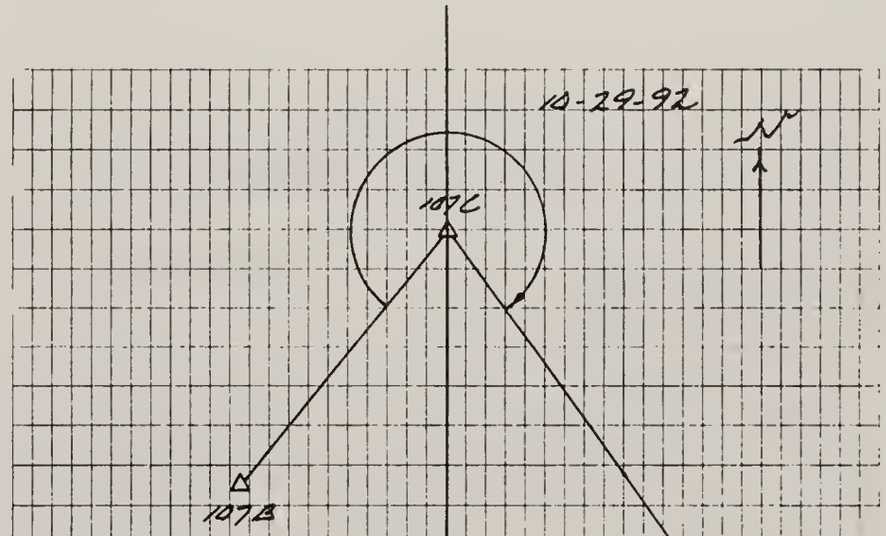
FORM CSN 02

Figure A-26
Solar Observation

Solar Observation @ 107C - BS 107B

		X	S.W
107B	D	00°00'00"	
D	D	283°49'36"	00:04:42.2
D	D	284°05'55"	00:06:02.2
D	D	284°14'55"	00:06:49.0
D	D	284°22'35"	00:07:27.3
D	R	104°49'20"	00:09:46.8
D	R	104°57'30"	00:10:26.8
D	R	105°07'15"	00:11:14.5
D	R	105°17'05"	00:12:04.3
107B	R	179°59'36"	

The above represents one set of observations. A complete observation consists of at least three sets.



Latitude (ϕ) = 47°08'37"N
Longitude (λ) = 110°49'18"W
ϕ & λ scaled from quad ∴ NAD 27

Stopwatch started @ 15:52:00 UTC
ΔUT = -0.2"
UTI = 15:51:59.8
Stopwatch slow 0.4"

Important:
The date must be included
A solar filter must be used with all total stations

FORM CSN-02

Figure A-27
Monument Notes – Sample 1

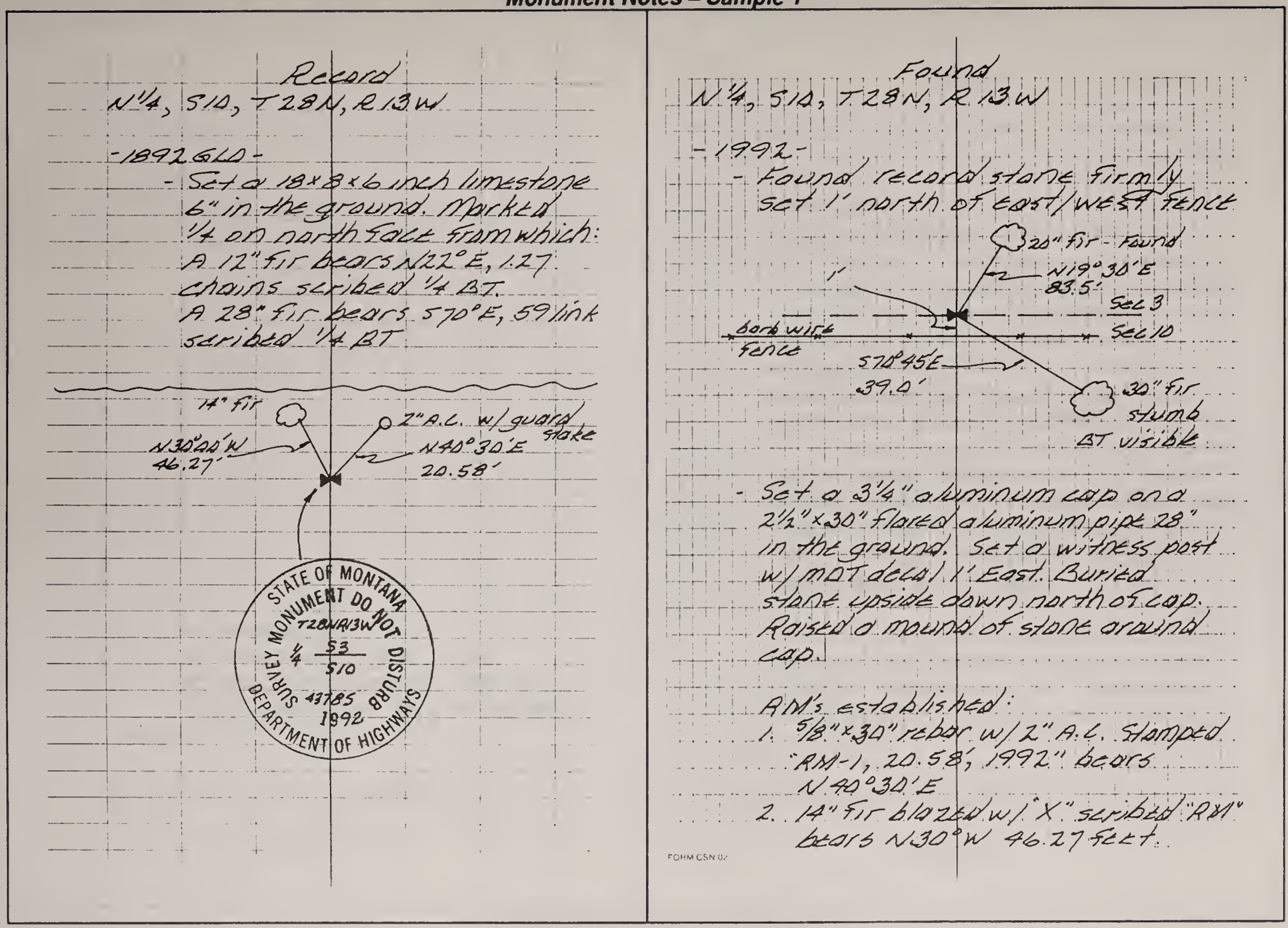

Record
N1/4, S10, T28N, R13W
-1892 GLO-
- Set a 18x8x6 inch limestone 6" in the ground. Marked 1/4 on north face from which:
A 12" fir bears N22°E, 1.27. chains scribed 1/4 BT.
A 28" fir bears S70°E, 59 link scribed 1/4 BT
14" fir
N30°00'W
46.27'
2" A.C. w/ guard stake
N40°30'E
20.58'
STATE OF MONTANA
MONUMENT DO NOT DISTURB
T28NR13W
1/4 S3 / S10
43785
1992
DEPARTMENT OF HIGHWAYS
Found
N1/4, S10, T28N, R13W
-1992-
- Found record stone firmly set 1' north of east/west fence
20" fir - Found
N19°30'E
83.5'
1'
Sec 3
Sec 10
barb wire fence
S70°45E
39.0'
30" fir stump BT visible
- Set a 3 1/4" aluminum cap on a 2 1/2" x 30" flared aluminum pipe 28" in the ground. Set a witness post w/ MOT deco/ 1' East. Buried stone upside down north of cap. Raised a mound of stone around cap.
AM's established:
1. 5/8" x 30" rebar w/ 2" A.C. stamped "AM-1, 20.58', 1992" bears N40°30'E
2. 14" fir blazed w/ "X" scribed "RM" bears N30°W 46.27 feet.
FORM CSN 0.

Figure A-28
Monument Notes – Sample 2

Record

N ¼, S30, T35, R22W

-1879 GLO-

- Set a 18x12x6 inch sandstone 12 inches in ground. Marked ¼ on north face. Pits impractical

Found

N¼, S30, T25, R22W

-1992-

- Searched for not found (SENF). Scaled distance from highway to corner using quad map - 1020'. Paced into area using compass.

Searched ± 1½ hours. Set a lath marked "Approx ¼" @ paced distance. Lath is in range land. No evidence suggests stone destroyed.

Should be search for again after ties made to section corner to the east.

FORM CSN 02

Figure A-29
Monument Notes – Sample 3

Record

Southwest corner S16, T15N, R43E

-1889 GLO-

- Set a 22x16x8 inch quartzite stone 16 inches in ground. Marked w/ 3 grooves on south and 4 grooves on east. Dug pits 18 inches square - 12" deep in each section @ 5½ feet distant.

Found

Southwest corner S16, T15N, R43E

-1992-

- SENE

Corner falls in wheat field. Mr. James Walker who farms the land was born-house located in SW¼ of Sec 16-in 1921. Grandfather homesteaded Sec 16 & 17. Father farmed the homestead. Mr. J. Walker doesn't know anything about this corner nor the S¼ corner of Sec 16. He doesn't recall his Grandfather or Father telling him anything either.

Corner is probably lost.

FORM CSN 02

Figure A-30
Monument Notes – Sample 4

Record

Southwest corner 55, T5N, R4E

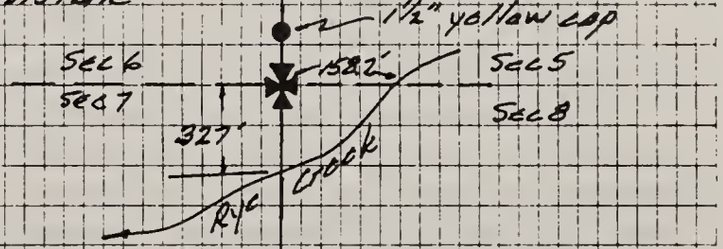
-1881 GLO-
- Set a 20 x 10 x 8 inch sandstone 4 inches in the ground. Marked w/ 5 notches on east and 5 notches on south. Dug pits 18 x 18 x 12 inches 5½ feet distant in each section

-1983 Recordation (in file)
- Found stone Firmly set.
- Set a 1½" yellow cap on a 5/8" x 24" rebar 1' north of stone. Cap marked "L.S. Slow 9995"

Found

Southwest corner 55, T5N, R4E

-1992-
- Found record stone firmly set. Pits visible NE + SE @ 5½' distance. 1½" yellow cap stamped per recordation 1' north. All notches visible



- Set a witness post w/ MOT decal 1' east of stone.
Raised a mound of stone 1' west of record stone.

FORM CSN-02

Figure A-31
Report on Relocation of Bench Mark

NOAA FORM 76-60 (6-71)
U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REPORT ON RELOCATION OF BENCH MARK

(See instructions on reverse side)

DESIGNATION OF MARK: T 194

STATE: MT | COUNTY: Fergus

A. DESCRIPTION OF ORIGINAL MARK

In Sec. 9, T 20 N, R 19 E. 3.75 southeast along the C, M, P, P railroad from the station at Winifred; thence 1.2 miles east along a graveled road, near west end of a curve and 56' north of centerline, and 57 NE of a power pole

PUBLISHED ON _____ STAMPING T 194 1961

B. WAS ORIGINAL BENCH MARK DESTROYED? ☐ YES ☒ NO HORIZONTAL CONTROL POINT? ☐ YES ☒ NO

REMARKS: T 194 will be destroyed due to bridge work

DATE OF LEVELING _____

(Feet or ~~Meters~~)*

POINT	B.S.	H.I.	F.S.	ELEVATION	REMARKS
T194				3420.443	
	3.172	3423.615			
T194 TBM			1.783	3421.832	Temporary B.M.
TBM T194				3421.832	
	2.097	3423.929			
T194			3.484	3420.445	Error = +0.002
Σ	+5.269	Σ	-5.267		Error = +0.002
					*Maximum error
					allowed = ±0.005

C. DESCRIPTION OF NEW MARK

STAMPING ON NEW MARK T 194 TBM

5/8" x 30" rebar w/ 2" aluminum cap. Stamped T 194 TBM, Dept. of Highways, Montana. At westerly edge of a power pole 57' S.W. of T 194 Drove metal witness post along side T 194 and T 194 TBM

*Strike out unit NOT used.

SIGNED James Holt

AGENCY MDT

Figure A-31 (Continued)
Suggestions for Relocating Bench Marks

When a bench mark is in need of relocation the proper procedure, in most cases, is to establish the new mark in a safe place nearby and level from the old mark to the new one by means of an engineer's level and rod. The leveling should be run in duplicate to avoid the possibility of large errors, and all readings should be made to three decimal places in order to preserve the accuracy of the original survey. **It is not necessary that the new mark be established at the same elevation as the old mark.** When necessary, two temporary bench marks may be established to hold the elevation until the new mark is in place.

The old mark should not be disturbed until the observations involved in the leveling have been checked by the observer or the recorder. An assumed elevation for the old mark may be used in the leveling, since we are principally concerned with the **difference of elevation** between the old mark and the new one.

Space is provided on the other side of this sheet for a copy of the field notes, the description of the original mark, description of the reset mart, and any remarks that seem desirable.

Hints, on description writing. — Directions should be compass directions, to the nearest half quadrant. If available, distances and directions to the mark form several nearby objects, such as poles, fences, trees, mileposts, culverts, etc., should be given to assist in recovery of the mark if it should be hidden in high grass or weeds. The distance and direction from the center line of the road or track followed by the level line should also be given.

The descriptions of the new mark should be so written as to enable a stranger unfamiliar with the surrounding territory to find and identify the mark with ease and certainty, having at his disposal only the data given in the description.

The cooperation which individuals and organizations may extend to this Bureau in preserving bench marks will be a service, not only to the Bureau and other government surveying organizations, but to all who may have occasion to use the marks in the future.

Figure A-32
Blank Form – Report on Relocation of Bench Mark

NOAA FORM 76-60 (6-71)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REPORT ON RELOCATION OF BENCH MARK

(See instructions on reverse side)

DESIGNATION OF MARK

STATE | COUNTY

A. DESCRIPTION OF ORIGINAL MARK

PUBLISHED ON _____ STAMPING _____

B. WAS ORIGINAL BENCH MARK DESTROYED? ☐ YES ☐ NO HORIZONTAL CONTROL POINT? ☐ YES ☐ NO

REMARKS

DATE OF LEVELING _____

*(Feet or Meters)**

POINT	B.S.	H.I.	F.S.	ELEVATION	REMARKS

C. DESCRIPTION OF NEW MARK

STAMPING ON NEW MARK _____

*Strike out unit NOT used.

SIGNED _____

AGENCY _____

Figure A-33
Base Line User Report

BASE LINE USER REPORT

BASE LINE NAME HELENA BASE LINE
COUNTY BROADWATER
INSTRUMENT OWNER MDOH
DATE OCTOBER 19, 1990
CREW BRYCE LARSEN - GARY TIMAR
WEATHER COOL / PARTLY CLOUDY / WINDY

	INSTRUMENT	REFLECTOR
MAKE	LIETZ	LIETZ
MODEL	SET 3	7266--34
SERIAL NUMBER	108389	CONSTANT 30MM (PRE-SET IN INSTRUMENT)
STANDARD DEVIATION	5 mm + 3 ppm	

MARK TO MARK

Instrument Station Reflector Station	0 M TO 150 M	0 M TO 430 M	0 M TO 1400 M	150 M TO 430 M	150 M TO 1400 M	430 M TO 1400 M
Temperature / Pressure (°F/"HG)	40° /25.5"	46° /25.6"	40° /25.5"	46° /25.6"	46° /25.6"	46° /25.6"
PPM	33	35	33	35	35	35
Height of Instrument (1)	(4.9') 1.49 M	(4.9') 1.49 M	(4.9') 1.49 M	(4.6') 1.40 M	(4.6') 1.40 M	(4.7') 1.43 M
Height of Reflector (1)	(4.3') 1.31 M	(4.5') 1.37 M	(4.8') 1.46 M	(4.5') 1.37 M	(4.8') 1.46 M	(4.8') 1.46 M
DH=HI-HS	0.18 M	0.12 M	0.03 M	0.03 M	-0.06 M	-0.03 M
X=Measured Distance (Record Five Readings)	150.016 M 150.017 M 150.017 M 150.017 M 150.017 M	429.981 M 429.990 M 429.990 M 429.989 M 429.990 M	1420.015 M 1420.015 M 1420.014 M 1420.015 M 1420.013 M	279.977 M 279.977 M 279.976 M 279.976 M 279.976 M	1270.024 M 1270.024 M 1270.025 M 1270.025 M 1270.024 M	990.133 M 990.133 M 990.133 M 990.133 M 990.134 M
Average Measured Distance	150.0168 M	429.9896 M	1420.0150 M	279.9764 M	1270.0244 M	990.1332 M
Measured Distance in Feet (2)	492.18 FT (150.017 CAL)	1410.72 FT (429.988 CAL)	4658.83 FT (1420.019 CAL)	918.56 FT (279.977 CAL)	4166.74 FT (1270.025 CAL)	3248.46 FT (990.133 CAL)
Observed Mark to Mark Distance= $\sqrt{X^2 - DH^2}$	150.0167 M	429.9896 M	1420.0150 M	279.9768 M	1270.0244 M	990.1332 M
NGS Mark to Mark	150.0151 M	429.9873 M	1420.0120 M	279.9732 M	1270.0253 M	990.1346 M
Difference	0.0016 M	0.0023 M	0.0030 M	0.0032 M	0.0009 M	0.0032 M

NOTES:
(1) Make all measurements including HI and HS in meters except for one slope distance in feet.
(2) This distance is for a check only and should not be used to reduce the measured distance to Mark to Mark.

Return copy to: Montana Department of Transportation, 2701 Prospect, Helena, MT. 59620
Attn: Photogrammetry and Survey Section.

Figure A-34
Blank Form – Base Line User Report

BASE LINE USER REPORT

BASE LINE NAME _____ COUNTY _____

INSTRUMENT OWNER _____ DATE _____

CREW _____ WEATHER _____

	INSTRUMENT	REFLECTOR
MAKE	_____	_____
MODEL	_____	_____
SERIAL NUMBER	_____	CONSTANT _____
STANDARD DEVIATION	_____ mm + _____ ppm	

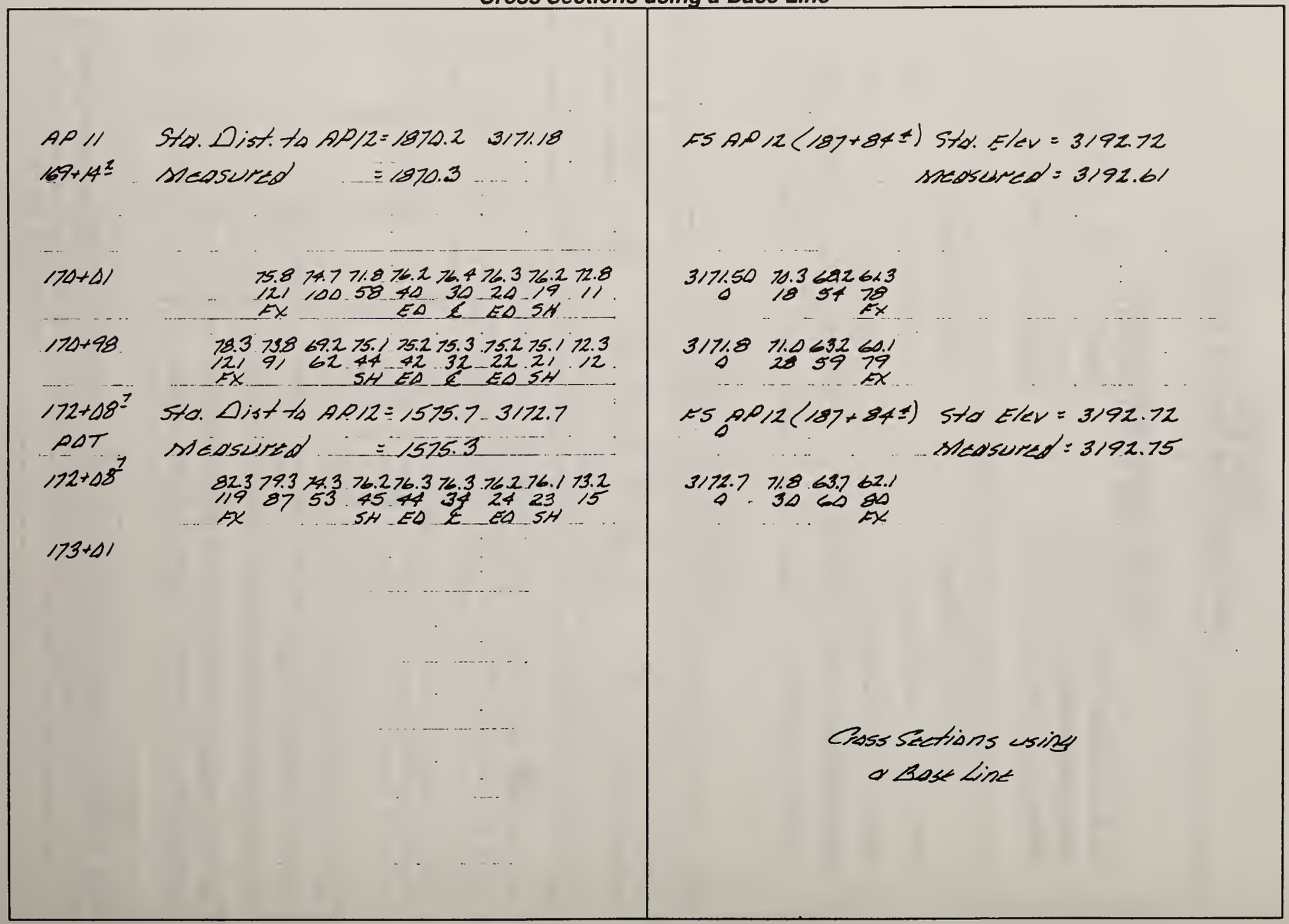
MARK TO MARK

Instrument Station Reflector Station	0 M TO 150 M	0 M TO 430 M	0 M TO 1400 M	150 M TO 430 M	150 M TO 1400 M	430 M TO 1400 M
Temperature / Pressure	/	/	/	/	/	/
PPM						
Height of Instrument (1)	M	M	M	M	M	M
Height of Reflector (1)	M	M	M	M	M	M
DH=HI-HS	M	M	M	M	M	M
X=Measured Distance (Record Five Readings)	M M M M M	M M M M M	M M M M M	M M M M M	M M M M M	M M M M M
Average Measured Distance	M	M	M	M	M	M
Measured Distance in Feet (2)	FT	FT	FT	FT	FT	FT
Observed Mark to Mark Distance= $\sqrt{X^2 - DH^2}$	M	M	M	M	M	M
NGS Mark to Mark	M	M	M	M	M	M
Difference	M	M	M	M	M	M

NOTES:
(1) Make all measurements including HI and HS in meters except for one slope distance in feet.
(2) This distance is for a check only and should not be used to reduce the measured distance to Mark to Mark.

Return copy to: Montana Department of Transportation, 2701 Prospect, Helena, MT. 59620
Attn: Photogrammetry and Survey Section.

Figure A-35
Cross Sections using a Base Line



AP 11 Sta. Dist. to AP12 = 1870.2 3171.18
169+14± Measured = 1870.3

170+01
75.8 74.7 71.8 76.2 76.4 76.3 76.2 72.8
121 100 58 40 30 20 19 11
FX ED E ED SH

170+98
78.3 73.8 69.2 75.1 75.2 75.3 75.2 75.1 72.3
121 91 62 44 42 32 22 21 12
FX SH ED E ED SH

172+08 Sta. Dist. to AP12 = 1575.7 3172.7
POT Measured = 1575.3

172+08
82.3 79.3 74.3 76.2 76.3 76.3 76.2 76.1 73.2
119 87 53 45 44 34 24 23 15
FX SH ED E ED SH

173+01

FS AP12 (187+84±) Sta. Elev = 3192.72
Measured = 3192.61

3171.50 70.3 69.2 61.3
0 18 54 78
FX

3171.8 71.0 63.2 60.1
0 28 59 79
FX

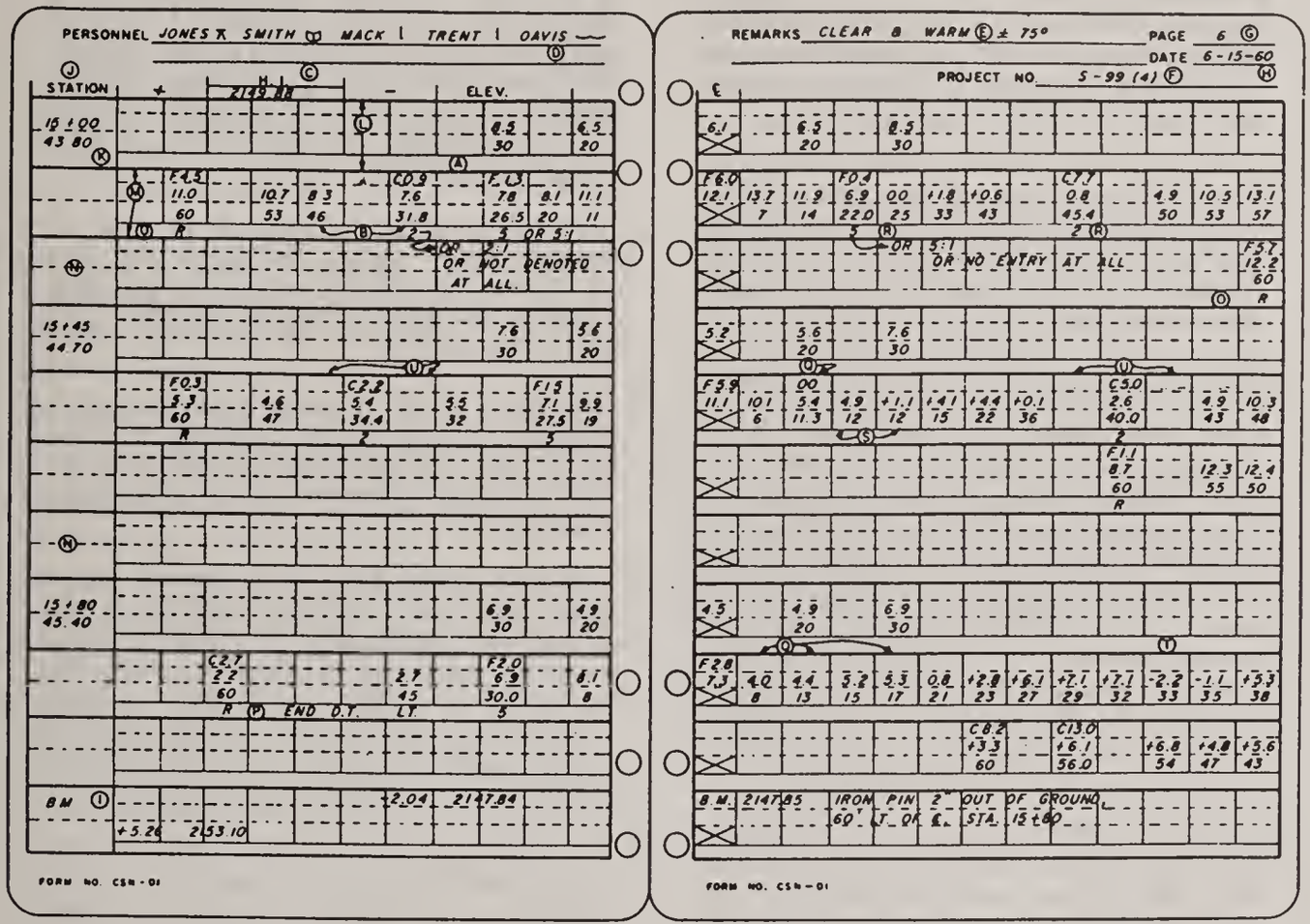
FS AP12 (187+84±) Sta Elev = 3192.72
0 Measured = 3192.75

3172.7 71.8 63.7 62.1
0 30 60 80
FX

Cross Sections using
a Base Line

Figure A-36
Sample Cross-Section Notes

"SAMPLE CROSS-SECTION NOTES"



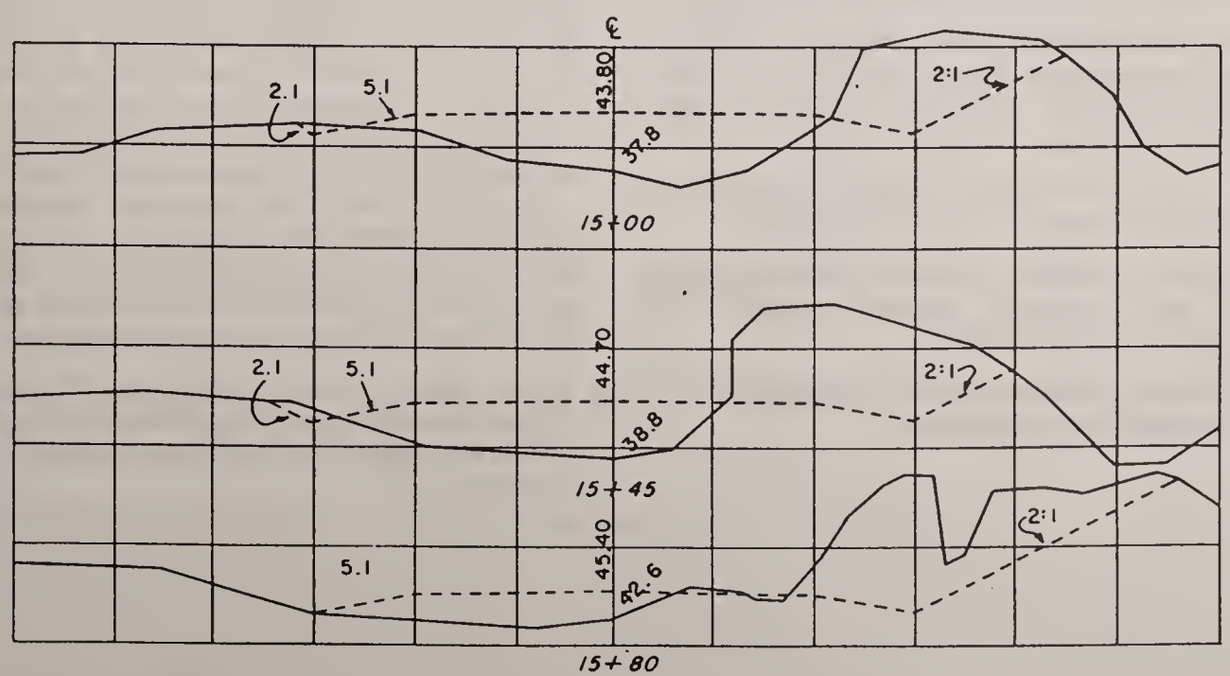


Figure A-36 (Continued)
Explanatory Notes

These notes explain the encircled letters, shown in various places on the cross-section notes.

A. All rod readings must be written to the nearest 0.1 (tenth) of a foot, even when the reading is an exact foot, such as 9.0. Decimal points must be clearly shown. The only sign to precede a rod reading is a "+" sign, other readings will be understood to be a minus (–). See Note T.

B. Record distances to the nearest foot (24) for most conditions. There will be cases when it will be necessary to record to the nearest 0.1 (tenth) of a foot (31.8), such as slope stakes, curbs, immovable structures, etc. Use decimal points when showing distances of less than 1 foot (0.7).

C. The HI (height of instrument) must be entered in this column at all times. It need not always be at the top of the page. If a turn is recorded near the middle of the page, the HI would occur there, but in this column. The punch card operators could miss it quite easily if it is carried elsewhere. When HI is carried forward from page to the next, enter it as shown at C. When a turn is made, or BM checked into, enter as shown at bottom of column. The recorder always must be careful to record HI in six figures. A common error is to incorrectly copy the first two figures and thus, be off a100 feet or more. The other headings (+, –, elev.) are self-explanatory.

D. Each day's work should show the names of the personnel doing the staking and the type of work each person does, such as instrument, rod, chain, etc. If a change in assignments is made during the day, it is desirable to note the change.

E. It is recommended that the "Remarks" space be used as occasion dictates. Weather conditions and temperature should be noted each day; more often, if noted conditions change.

F. The project number or identification should be shown frequently — even on every page.

G. Project managers may devise their own system of page numbering. Positive identification in proper sequence is important.

H. The date should be entered, at the least, at the beginning of each day's work.

I. Bench marks and turning points (BM & TP) should be recorded as shown. The method shown is used by most project managers. A complete description must be provided as to type and location of BMs. TPs are not so important; most are temporary for the one turn; although some are used several times. The type of use and reuse should be considered.

J. This column should be used at all times for recording station number and station plus number. The first entry in this column, on any page, should be complete as to station and plus — write 136+17, not just +17.

K. The figure "43.80" is profile grade reduced to subgrade elevation by the surfacing thickness. Some project managers prefer to write "2143.80." This information should be inserted in this space on all pages.

L. A four-line space, such as "L" and "M" will be called "quad-space" in further discussions. The template rods (grade rods) and distances always should be written into the same quad-space as the station and grade. The template readings should show all of the breaks in the completed roadway section, excepting the outside catch points where template intersects the ground.

M. The first quad-space below the template notations is used for groundline readings. It also will carry slope stake data and other pertinent information, such as illustrated. The lower of the four spaces of the quad-space, which has no vertical lines, is used for notations such as rate of slope (5:1 or 5), reference (R), end cut, etc. This applies to both template and groundline readings. It is a frequent occurrence for so many ground readings to be recorded that all cannot be entered on one line. In such cases, proceed as illustrated on the right side for Station 15+45. On the right side, the first line should read from left to right, the second right to left, the third left to right, etc. The left side of centerline would be the opposite.

N. Always leave at least one quad-space between the last quad-space used for a cross section and the first quad-space used for the next section. Do not crowd notes.

Figure A-36 (Continued)
Explanatory Notes

These notes explain the encircled letters, shown in various places on the cross-section notes.

O. Reference stake or reference point entries should be shown as In Figure 11-1. There will be occasions, such as a channel change near the outside of the right of way, when the project manager will want the reference point between such a channel and the roadway. Write "R" under whichever point is selected and record on out to the decided limit.

P. The project manager frequently will desire to enter such notes as "end ditch left," "begin cut right, " etc. Such notes can be entered as shown at Sta. 15+80 left side. (Requires an entire section for calculation.)

Q. Note that at Sta. 15+45 the 00/11.3 was found and recorded. There actually are three "00s" at Sta. 15+80 between centerline and 10 feet right; they were not caught. The electronic computer will interpolate them automatically.

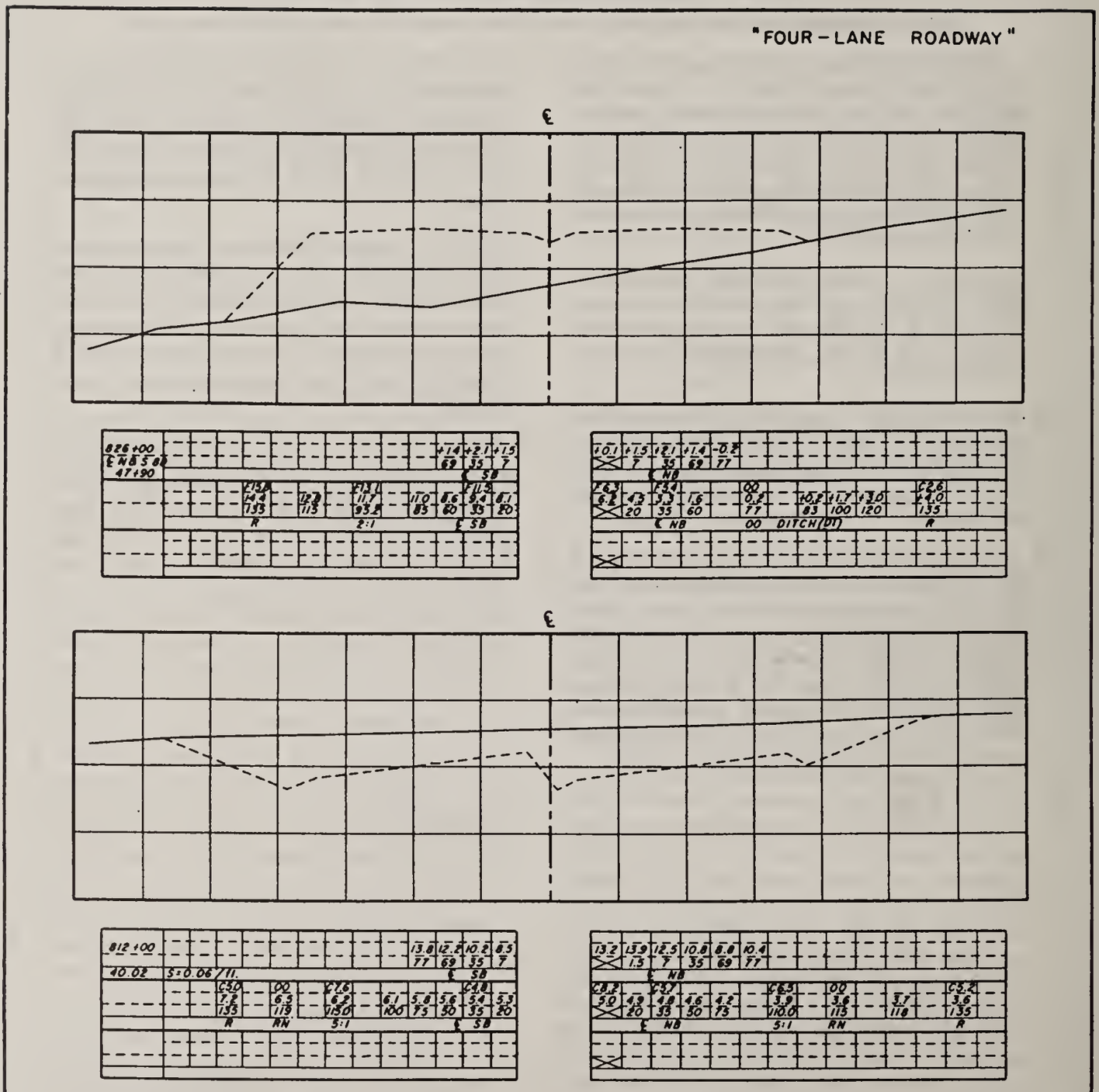
R. Some project managers prefer to record the rate of fill slope or cut slope stake readings. See Sta. 15+00, readings at 22.0 and 45.4. The fill slope or in-slope is 5:1, recorded as 5; the back slope is 2:1 and recorded as 2. In a daylight situation recorder enters "DL" below the reading (00/5.4/35.7/DL). The recorder may indicate the rate of slope by either "5" or "5.1." Such entries are not necessary for electronic computation.

S. Vertical faces or situations can be entered in the notes at the actual distance without having to add or subtract any amount. Three, but no more, readings at the same distance can be recorded for either groundline or template or both.

T. When the project manager has a series of plus rods and in between has one or two minus rods, it would be helpful if the minus sign were entered in front of the rod reading, as shown at Sta. 15+80 right. Such an entry clears up any doubt that might occur to the reader.

U. At least one blank space would be left in the notes on each side of the outside catch shot, as shown for Sta. 15+45. This makes it much easier for punch card operators to find the first and last template readings.

Figure A-37
Cross-Section Notes for Four-Lane Highway



THE TWO SECTIONS ILLUSTRATED ON THIS PLATE SHOW ONE WAY OF STAKING A FOUR-LANE HIGHWAY. THE UPPER SKETCH SHOWS A SECTION ON TANGENT. THE LOWER A SECTION ON A CURVE. THERE ARE SEVERAL METHODS THAT CAN BE AND ARE USED. THIS ONE SEEMS TO WORK OUT QUITE WELL. THESE SKETCHES SHOW HOW THE NOTES SHOULD BE KEPT FOR ELECTRONIC COMPUTATIONS. THEY WILL WORK EQUALLY WELL FOR HAND CALCULATOR COMPUTATION IF ALL 00'S, AS WELL AS ALL SLOPE STAKES, ARE FOUND AND RECORDED.

THE IMPORTANT FEATURE IS THAT ALL ENGINEERS ADOPT AND USE A UNIFORM SYSTEM OF RECORDING NOTES, SUCH AS SET OUT IN THIS SECTION OF THE MANUAL.

IF AND WHEN PARALLEL DITCHES, DIKES, ROADWAYS, ETC., ARE TO BE STAKED ALONG WITH AND AT THE SAME TIME AS THE MAIN ROADWAYS, THE TEMPLATE NOTES, AS WELL AS THE GROUND-LINE NOTES, CAN BE EXTENDED TO INCLUDE THOSE FACILITIES. PLATE VII-05-03 PROVIDES ONE METHOD OF HOW TO PROCEED.

Figure A-38
Cross-Section Notes for Borrow Widening

CASE 1. "BORROW WIDENING"

CASE 1. THIS EXAMPLE SHOWS A NORMAL FLAT BOTTOM DITCH SECTION AND THE APPROVED METHOD OF RECORDING GROUND AND TEMPLATE NOTES.

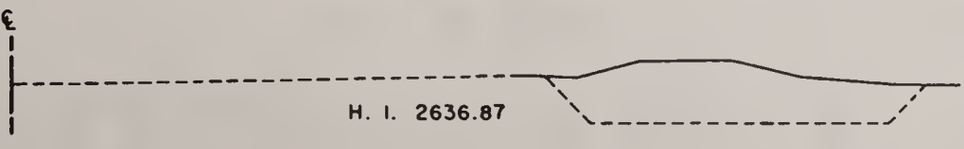
Template	4.0 / 00		10.0 / 20		13.3 / 35			13.3 / 68	
			F1.8					C6.3	
Ground	12.7 / 00	12.0 / 13	11.8 / 29.0	11.8 / 32	10.0 / 42	10.0 / 55	6.6 / 65	7.0 / 74.3	7.5 / 80

CASE 2.

Template	8.9 / 100	5.5 / 110	5.5 / 120	10.0 / 130	10.0 / 140		
						C6.2	
Ground	3.3 / 90	0.5 / 100	0.5 / 115	3.0 / 125	3.8 / 140	3.8 / 146.2	3.8 / 150

CASE 2. THE ENGINEER FOUND IT NECESSARY TO EXTEND THE CROSS-SECTION NOTES TO WIDEN THE BORROW, AND TO BUILD A BERM AND CHANNEL AFTER STAKING THE SECTION IN CASE 1. THE EXTENSIONS CAN BE STAKED USING THE SAME OR A DIFFERENT H.I., THEN CONTINUING ON TO THE RIGHT AS ILLUSTRATED UNDER CASE 2. SEPARATE NOTES ARE KEPT FOR THE EXTENSIONS BUT THE ENGINEER MUST MAKE THE EXTENSIONS STATION FOR STATION WITH THE ORIGINAL NOTES SO THE QUANTITIES INVOLVED WILL BE CALCULATED AND INCLUDED WITH THE ORIGINAL STAKED QUANTITIES. THE ORIGINAL NOTES MUST BE AMENDED BY DRAWING A RED LINE THROUGH THE C 6.3.

CASE 3.



(A) 10.0 / 00	Template	9.5 / 80	9.6 / 86.2	16.4 / 93						16.4 / 140		
			C6.8								C6.2	
(A) 10.0 / 00	Ground	9.5 / 80	9.6 / 86.2	9.7 / 90	6.9 / 100	6.9 / 115	9.4 / 125	10.2 / 140	10.2 / 146.2	10.2 / 150		

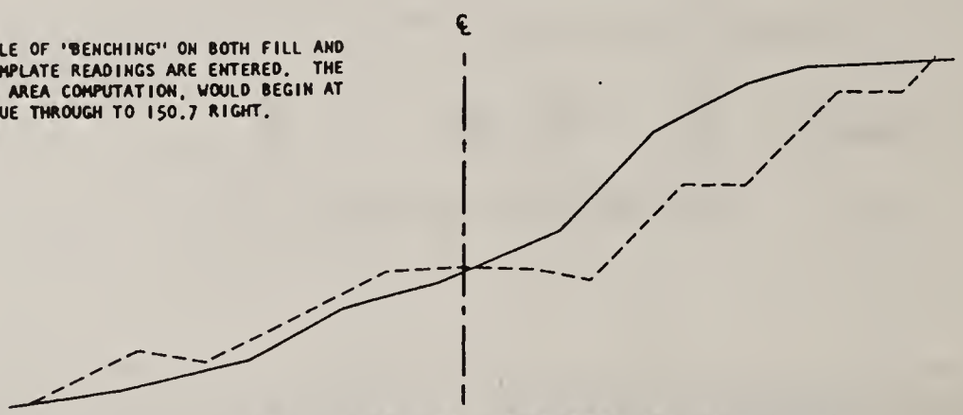
CASE 3. HERE THE ENGINEER DOES NOT WISH TO EXTEND THE ORIGINAL CROSS-SECTIONS, BUT RATHER TIE BACK TO CENTERLINE OR BASELINE BY INSERTING "FAKE" READINGS AT "A" AND REPEATING THE GROUNDLINE READINGS AT 80 AND 86.2 IN THE TEMPLATE READINGS SUCH THAT NO AREA CALCULATIONS WILL BE MADE BETWEEN 00 AND 86.2. THE VOLUMES CALCULATED IN CASE 3 WILL BE SEPARATE FROM THOSE ORIGINALLY STAKED.

THE CROSS-SECTIONS MUST BE TAKEN AT THE SAME SECTIONS AS ON CENTERLINE, IF TO BE MERGED WITH CENTERLINE QUANTITIES.

Figure A-39
Cross-Section Notes for Benching and Pavement Widening

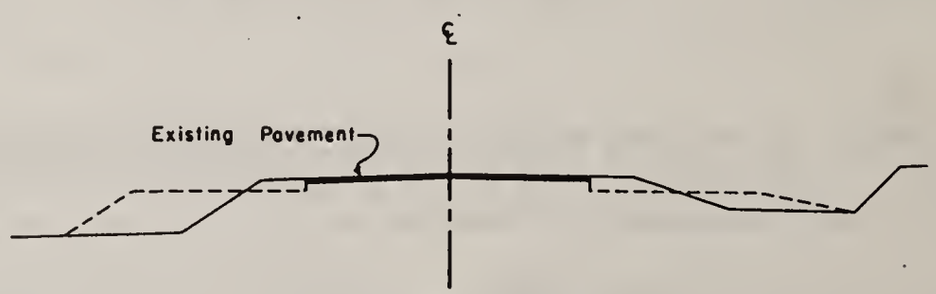
"BENCHING"

THIS IS AN EXAMPLE OF "BENCHING" ON BOTH FILL AND CUT. NOTE HOW THE TEMPLATE READINGS ARE ENTERED. THE TEMPLATE SECTION, FOR AREA COMPUTATION, WOULD BEGIN AT 137.8 LEFT AND CONTINUE THROUGH TO 150.7 RIGHT.



Template			67.6/105	70.6/85	40.6/25	40.0/X	40.4/20	44.4/40	14.4/70	14.9/90	+15.1/120	+14.6/140	
Ground	F45.0/85.0/145/R	F16.4/84.0/137.8	80.0/110	90.0/70	54.2/40	45.5/9	41.6/X	00/40.1/5.0	28.2/30	+2.9/61	+17.4/90	+23.3/110	C10.7/+25.3/150.7	C66.0/+26.6/155/R

"PAVEMENT WIDENING"



Template					3.5/9	2.8/9	2.4/X	2.7/9	3.5/9				
Ground	6.6/28/R		6.3/17	00/3.6/13.2/DL	2.9/12	2.8/9	2.4/X	2.7/9	2.8/12	00/3.6/14.7/DL	4.8/18	4.9/26	2.0/29	2.0/30

THIS ILLUSTRATES WHAT IS PRIMARILY A SURFACING PROJECT OVER WIDENING OF EXISTING PAVEMENT. THE TEMPLATE AND GROUNDLINE READINGS WOULD BE ABOUT AS SHOWN. THE ONLY QUANTITIES TO BE DETERMINED ARE EXCAVATION. THE SHOULDERS WILL BE OBTAINED BY BLUE-TOPS AND THE SLOPES BY MACHINERY

Appendix B
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Appendix C
Glossary

The Glossary includes definitions, abbreviations and surveyor's measures and conversions.

Definitions C-2

Abbreviations C-35

Surveyor's Measures and Conversions C-42

- Constants C-42
- Abbreviations C-43
- Measures C-44
- Conversions C-45

Definitions

A

Abstract. A summary of the important aspects of survey control points that are listed after the computations are complete. The abstract should contain the following information: point identification number, the northing (Y), the easting (X), the elevation of the control point (Z), the elevation of the ground, the description, marking, and how-to-reach information.

Accessories to corners (USPLS). Physical objects adjacent to corners to which the corners are referred for their future identification or restoration. Accessories include bearing trees, mounds, pits, ledges, rocks, and other natural features to which distances or directions from the corner or monument are known. The accessories are actually a part of the monuments.

Accuracy. The degree of conformity with a standard, or the degree of perfection attained in a measurement. Accuracy relates to the quality of a result, and is distinguished from precision, which relates to the quality of the operation by which the result is obtained.

Acknowledgment. A formal declaration by an individual before some competent public officer declaring it to be his/her act or deed — usually declared before a notary public.

Adjusted position. An adjusted value for the horizontal or vertical position of a survey station, in which discrepancies due to errors in the observed data are removed. This adjustment forms a coordinated and correlated system of station.

Aerial photography. Any photography taken from the air — sometimes called aerial photo.

Aerial survey. A survey using aerial photographs as part of the surveying operation.

Altitude. The vertical angle between a horizontal plane and the line to the observed or defined object. In surveying, a positive altitude (measured upward from the horizon) is termed an angle of elevation, and a negative altitude (measured downward from the horizon) is termed an angle of depression. Altitude is sometimes used to apply to elevation above a datum, the altitude of an airplane above ground, or above sea level.

Angle. The difference in direction between two convergent lines. It may be classed as horizontal, vertical, oblique, spherical, or spheroidal, according to whether it is measured in a horizontal, vertical, or inclined plane, or in a curved surface.

Angle, central.

- The angle at the center of a radius of a circular arc included between the radii that pass through beginning (PC) and end (PT) of the arc. This angle is equal to the change in direction of the tangents to the arc that pass through the PC and PT. In alignment surveys, it is commonly called the delta angle.
- The angle in curve systems containing compound curves, or spiral and circular curves, between the beginning and ending radius, or the beginning and ending tangents. For spirals the central angle is called theta.

Angle, deflection. A horizontal angle measured from the prolongation of the preceding line, right or left, to the following line.

Analytical aerial triangulation. A photo-triangulation procedure in which the spatial solution is obtained by computational routines. Often called bridging.

Annotated photography. A photograph on which planimetric, topographic, geologic, cultural, hydrographic, or vegetation information has been added to identify, classify, outline, clarify, or describe features that would not otherwise be apparent in examination of an unmarked photograph.

Aperture.

- An opening; particularly that opening in the front of a camera through which light rays pass when a picture is taken, or
- The diameter of the objective lens of a telescope or other optical instrument, usually expressed in inches, but sometimes as the angle between lines from the principal focus to opposite ends of a diameter of the objective lens.

Auto positive. A black and white reproduction, as of a map or a plan, on transparent film in positive form made directly from a positive. A material that gives a positive copy from a positive transparency (or negative from a negative) by direct development. Also termed direct copy or direct positive.

Azimuth. The horizontal angle measured clockwise between the reference meridian and the line to an observed or described point. See "Grid azimuth," "Magnetic azimuth," "Forward azimuth," and "Back azimuth."

Azimuth line (photogrammetry). A line radial from the principal point, isocenter, or nadir point of an aerial photograph, which represents the direction to the corresponding image point on an adjacent photograph taken on the same flight line. This line is used extensively in radial triangulation.

Azimuth mark. A mark set at a significant distance from a triangulation or traverse station to mark the end of a line for which the azimuth has been determined, and to serve as a starting or reference azimuth for later use.

B

Back azimuth. The azimuth of a line at the end opposite the reference end. Back grid azimuths differ by 180 degrees from forward grid azimuth. Back astronomic and geodetic azimuths differ by 180 degrees plus or minus to convergence of the meridian from the astronomic or geodetic azimuths.

Backsight.

- In traversing, a backsight (BS) is a sight on a previously established traverse or triangulation station, which is not the closing sight of the traverse; and
- In leveling, a backsight is a reading on a calibrated rod held vertically on a point whose elevation has been previously determined, and which is not the closing sight of a level line.

Base line. Also see "Line, base (USPLS)." A base line is:

- a surveyed line established with more than usual care, to which surveys are referred for coordination and correlation, or
- (for construction) the center line of location of a railway or highway. A reference line for the construction of a bridge or other structure.

Basic control. Horizontal or vertical control, the positions of whose stations have been accurately coordinated and correlated forming a framework to which other surveys are adjusted.

Bearing. The directions of one point or object with respect to another, where the direction of the line is expressed by the acute angle with respect to the reference meridian. Bearings are measured clockwise or counterclockwise from north or south, depending on the quadrant.

Bench mark. A relatively permanent object, natural or artificial, bearing a marked point whose elevation above or below an adopted datum is known. Usually designated as a BM, such a mark is sometimes further qualified as a PBM (permanent bench mark), or a TBM (temporary bench mark).

Block adjustment. The adjustment of strip coordinates or photograph coordinates for two or more strips of photographs.

Bridging, analog. The photogrammetric measurement of points in a stereoscopic model and their adjustment to points of horizontal and vertical control. The horizontal position and elevation so determined for the intermediate points between the control are known as bridged supplemental control points.

C

C-factor. An empirical evaluation which expresses the vertical (elevation) measuring capability of a stereoscopic system; generally defined as the smallest contour interval that can be plotted to required accuracy. The C-factor is often used to determine the flight height from which aerial photographs should be taken for photogrammetrically accomplishing topographic mapping, at the smallest contour interval accurately plottable from using a particular aerial camera and instrument system. The practicable flight height is the contour interval multiplied by the C-factor.

Cairn. An artificial mound of rocks, stones, or masonry, usually conical or pyramidal, whose purpose is to designate or to aid in identifying a point of surveying or cadastral importance.

Call (USPLS). A reference to, or statement of, an object, course, distance, or other matter of description in a survey or grant requiring or calling for a corresponding object, or other matter of description, on the land.

Camera station. The point in space occupied by the camera lens at the moment of exposure.

Cartography. The art and science of expressing graphically, by maps and charts, the known physical features of the earth, or of another celestial body; usually includes the works of mankind and his varied activities.

Chain. A unit of length used in the subdivision of public lands of the United States. The Gunter's chain is 66 feet long and is divided into 100 links, each link being 7.92 inches long. (Early chains were 50 links, or 33 feet in length.)

Chaining. Measuring distances on the ground using a chain.

Chord. A straight line connecting two points on a curve.

Circle (surveying instrument). The circular disc of a surveying instrument which is perpendicular to and centered about an axis of rotation and on the perimeter of which graduations have been etched to accurately represent the magnitude of rotation. The horizontal and vertical circle intersection of the graduations of theodolites and transits with an index mark or vernier represents the angle measure when the coincidence of a sighting point is subtracted from the coincidence of a sighting on another point.

Circle position. A prescribed setting (reading) of the horizontal circle of a directional theodolite, to be used for the observation on the initial station of a series of stations that are to be observed.

Circuit closure. In leveling, the amount by which the algebraic sum of the measured differences of elevation around a circuit fails to equal the theoretical closure, zero.

Clockwise angle. A horizontal angle measured to the right. A clockwise angle may have any value between zero degrees and 360 degrees. Azimuths are clockwise angles generally measured from either north or south.

Closed traverse. A traverse that begins at a control point of known or adopted position and closes back to the same beginning point or closes to a second or subsequent known control point. The preferred method is to begin at one known control point and close to a second or subsequent known control point. This gives a positive check of the orientation of the traverse.

Closing error. See "Error of closure."

Closing the horizon. Measuring the last of a series of horizontal angles at a station. At any station, the sum of the horizontal angles between adjacent lines should equal 360 degrees. The amount by which the sum of the measured angles fails to equal 360 degrees is the angular error of closure. This error is distributed as a correction among the measured angles to make their sum exactly 360 degrees. The error and the correction have opposite algebraic signs.

Coincidence (bubble viewing). A prismatic arrangement common to leveling instruments and some theodolites, wherein one-half of opposite ends of the leveling bubble are brought into view in a single image. Coincidence is achieved when the two halves of the bubble ends match.

Collimation, error of. The angle between the line of collimation (line of sight) of a telescope and its collimation axis. When the collimation adjustment of an instrument is perfect (which is never the case) the line of collimation and the collimation axis will coincide, and the error of collimation will be zero. In practical work, the adjustment is carried to where the error is so small that it can be considered to be negligible. Error of collimation is a systematic error and in a series of observations is usually treated as being of the constant error type.

Commencing, point of. In metes and bounds description, the starting point if not a part of the tract being described, e.g., "Commencing on the northwest corner of Section 12, T.44N., R.67W., 6th P.M., thence southerly along the west line of said section 500 feet to the point of beginning."

Continuation. Should be applied to a curved line. A curved is "continued" whereas a straight line is "prolonged."

Connecting traverse. A closed traverse that starts and ends at different stations whose relative positions have been determined by other surveys.

Contour line. An imaginary line on the ground, all points of which are at the same elevation above or below a specified datum.

Contour interval. A predetermined difference in elevation (vertical distance) at which contour lines are drawn. The contour interval is usually the same for maps of the same scale.

Contour map. A map that portrays relief by means of contour lines.

Control. A system of points whose relative positions have been determined from survey data. See "Basic control," "Horizontal control," "Vertical control" and "Picture point."

Control, geodetic. A system of horizontal and/or vertical control stations that have been established and adjusted by geodetic methods and in which the shape and size of the earth (geoid) have been considered in position computations.

Control, horizontal. Control with horizontal positions only. The positions may be referred to geographic parallels and meridians or to other lines of reference, such as plane coordinates.

Control, level. A series of bench marks or other points of known elevation, established throughout a project.

Control, photo. Any station in a horizontal and vertical control system that is identified on a photograph (usually alternating photos in a stereo overlap strip) and used for correlating the data shown on that photograph; also termed photo control point, picture control point, and ground control point.

Control station. A station whose position (horizontal or vertical) has been determined from survey data, and is used as a base for a dependent survey.

Control survey. A survey that provides positions (horizontal or vertical) of points to which supplementary surveys are adjusted.

Control traverse. A main scheme closed traverse which is performed to the highest degree of precision used on a project. The control traverse is used as the horizontal datum base for all aspects of a project. Secondary traverses to such things as topographic features, aerial targets and property corners are tied to the control traverse.

Conventional Survey. A centerline survey where data is recorded by stations and offsets. This type generally is restricted to overlay projects.

Coordinate. To place survey data on the same system of coordinates or datum. "Coordinate" does not imply the adjustment of observations to remove discrepancies. Two surveys over the same area are coordinated when they are computed on the same datum. Discrepancies that remain are removed by adjustment to correlate the data.

Coordinates. Linear or angular quantities, or both, which designate the position of a point in relation to a given reference frame. There are two general divisions of coordinates used in surveying: polar coordinates and rectangular coordinates. These may be subdivided into four classes: plane coordinates, spherical coordinates, grid coordinates, and geodetic coordinates.

Corner. A point on a land boundary, at which two or more boundary lines meet. Not the same as monument, which refers to the physical evidence of the corner's location on the ground.

Corner (USPLS). A point on the surface of the earth, determined by the surveying process, marking an extremity of a boundary of a subdivision of the public lands, usually at the intersection of two or more surveyed lines; often incorrectly used to denote the physical structure, or monument, erected to mark the corner point. Corners are described in terms of the points they represent.

Corner, closing (USPLS). A corner at the intersection of a surveyed line with a previously established boundary line. To compensate for convergence of the meridians, standard parallels (once termed "correction lines") are established at intervals of 24 miles. These were formerly established at varying intervals up to 60 miles. Corners established at the time the standard parallel is run are termed "standard corners" and govern the surveys to the north. A second set of corners — closing corners — is established at the point where the survey lines from the south intersect the standard parallel. Closing corners are also established at the boundaries of reservations, grants, claims, and other previously surveyed or segregated tracts of land.

Corner, double (USPLS). Normally the two sets of corners along a standard parallel; the standard township, sections, and quarter-section corners placed at regular intervals of measurement; additionally, the closing corners established on the line at the points of intersection of the guide meridians, range and section lines of the surveys brought in from the south.

Corner, existent (USPLS). A corner whose position can be identified by verifying the evidence of the monument, or its accessories, by reference to the description that is contained in the field notes, or where the point can be located by an acceptable supplemental survey record, some physical evidence, or testimony. Even though its physical evidence may have entirely disappeared, a corner will not be regarded as lost if its position can be recovered through the testimony of one or more witnesses who have a dependable knowledge of the original location.

Corner, found. A term adopted to designate an existent corner of the public-land surveys that has been recovered by field investigation.

Corner, lost (USPLS). A previously established survey corner whose positions cannot be recovered beyond reasonable doubt, either from traces of the original marks or from acceptable evidence or testimony that bears on the original position, and whose location can be restored only by reference to one or more interdependent corners.

Corner, meander (USPLS). A corner established at the intersection of standard, township or section lines with the banks of navigable streams or any meanderable body of water. See also "Corner, (USPLS)."

Corner, obliterated (USPLS). A corner at which there are no remaining traces of the monument or its accessories, but whose location has been perpetuated or may be recovered beyond reasonable doubt, by the acts and testimony of the interested landowners, competent surveyors, other qualified local authorities, witnesses, or by some acceptable record evidence. A position that depends upon the use of collateral evidence can be accepted only as duly supported, generally through proper relation of known corners, and by agreement with the field notes regarding distances to natural objects, stream crossings, line trees, and off-line tree blazes, etc., or unquestionable testimony.

Corner, witness (USPLS). A witness corner, by conventional usage, is a monumented point usually on a line of the survey and near a corner. It is employed in situations where it is impracticable to occupy the site of a corner. When the true point for a corner falls upon an inaccessible place (such as within an unmeandered stream, lake, or pond, or in a marsh, or upon a precipitous slope of cliff), where the corner cannot be occupied, a witness corner will be established at some suitable point where the monument may be permanently constructed, but preferably on a line of the survey. Usually only one witness corner will be established in each instance and it will be located upon any one of the surveyed lines leading to a corner, if a secure place within a distance of 10 chains is available. If there is not a place to be found on a surveyed line within that limiting distance, that can be occupied and marked, a witness corner may be located in any direction within a distance of 5 chains. If a monument replacement is involved using witness corner, and a specific distance given is a direct tie, no form of proration is acceptable.

Correlate. To remove discrepancies that may exist among survey data, so that all parts are interrelated without apparent error. The terms "coordinate" and "correlate" are usually applied to the harmonizing of surveys of adjacent areas or of different surveys over the same area. Two or more such surveys are coordinated when they are computed on the same datum; they are correlated when they are mutually adjusted.

Curve, circular. A curve of constant radius. All points on the curve are equal distance from the center of the circle.

Curve, compound. Name for two circular curves of different radii which are tangent at one point with both curves lying on the same side of the common tangent.

Curve, degree of. The degree of curve (D) defines the radius of a highway or railroad circular curve. There are two definitions:

- (chord) The angle subtended at the center of a circle by a chord of 100 feet, and
- (arc) The angle subtended at the center of a circle by an arc of 100 feet.

Definition 1 was used in railroad and early highway design. Definition 2 is used in present-day engineering of highway design.

D

Datum. Any numerical or geometrical quantity or set of such quantities that may serve as a reference or base for other quantities. For a group of statistical references, the plural form is data — as geographic data for a list of latitudes and longitudes. Where the concept is geometrical and particular, rather than statistical and inclusive, the plural form is datums, as, for example, two geodetic datums have been used in the United States in recent years.

Datum, adjusted (plane coordinates). The datum of a system of plane coordinates in a raised or lowered position from the initial datum on which the plane coordinate system was initially projected by mathematical procedures. The adjusted datum is always parallel to the initial datum. Position of the adjusted datum, above or below the initial datum, is governed by the degree to which reduction is made in the inherent differences between distance measured on the ground, and distances computed using plane coordinates of points and features delineated on maps compiled, or survey distances computed and/or measured on the adjusted datum.

Datum adjustment factor. A combined scale and elevation factor used to raise the coordinate values of a point from the state plane datum to that of the modified or surface plane.

Datum, horizontal. The position on the spheroid of reference assigned to the horizontal control (triangulation and traverse) of an area and defined by:

- the position (latitude and longitude) of one selected station in the area, and
- the azimuth from the selected station on an adjoining station.

The horizontal-control datum may extend over a continent or be limited to a small area. A datum for a small area is usually called a local datum and is given a proper name. The horizontal-control datum for the North American continent is known as the North American datum of 1927, the initial station of which is Meades Ranch, in Kansas, with the azimuth to station Waldo. All geodetic positions on the North American datum of 1927 depend on the position of Meades Ranch and the azimuth to Waldo.

Datum, local. The point of reference of the geodetic control used exclusively in a small area. Usually identified by a proper name.

Datum, mean sea level. A determination of mean sea level that has been adopted as a standard datum for heights or elevations. The Seal Level Datum of 1929, the current standard datum for geodetic leveling in the United States, is based on tidal observations over a number of years at various tide stations along the coasts.

Datum, state plane coordinates. The surface onto which each point of concern is transferred mathematically from the corresponding point on the earth spheroid to give its map position. For illustrative purposes, the Lambert conformal project datum is thought of as being represented by a cone and the Transverse Mercator projection datum by a cylinder, after each has been rolled out flat, or as a plane for other projects. Projection of distances between points on the ground to the datum is a two-stage process, first from the surface of the ground to the spheroid and, second, from there to the datum. Thus, the map is, in effect, a scale reproduction of the cone or cylinder rolled out flat. These datums are below the sea level arc of the earth between the lines of intersection of the cone or the cylinder with the spheroid, and are above the sea level arc for all segments of their surface outside such lines of intersection with the spheroid.

Declination.

- (Astronomy) The angle at the center of the celestial sphere between the radius passing through a celestial body and the plane of the celestial equator. Astronomic declination is measured by the arc of the hour circle between the celestial body and the equator; it is plus when the body is north of the equator and minus when south of it. It corresponds to latitude on the earth and with right ascension forms a pair of coordinates which define the position of a body on the celestial sphere.
- (Magnetic) the bearing (reckoned east or west from the north branch of the celestial meridian plane) of magnetic north as determined by the positive pole of a freely suspended magnetic needle that is subject to no transient artificial disturbance. In nautical and aeronautical navigation, the term "magnetic variation" is used instead of "magnetic declination," and the angle is termed "variation of a compass" or "magnetic variation."

Deflection angle. A horizontal angle measured from the prolongation of the preceding line, clockwise or counterclockwise as necessary, to the following line.

Departure. In a plane survey, the amount that one end of a line is east or west of the other end. The plane coordinates of a point are known as the easting and northing of the point and the departure is the difference between the eastings of the two ends of the line, which may be either plus or minus.

Direction. The angle between a line and an arbitrarily chosen reference line. When the reference line is north or south and the angle is designated east or west and less than 90 degrees, the direction is called the bearing. When the reference line is north or south and the angle is clockwise between 0 degrees and 360 degrees, the direction is called the azimuth.

Directional instrument. A theodolite, generally of high precision, in which the graduated horizontal circle remains fixed during a set of observations and the direction of each point of the instrument is read on the circle. Horizontal angles cannot be repeated or accumulated on a direction instrument, but the circle can be shifted in position between successive sets of observations.

Direct reading. The reading of the horizontal or vertical circle of a theodolite or engineer transit with the instrument direct. In field notes, a direct reading is indicated by the letter D preceding the observed value.

Discrepancy.

- The difference between duplicate or comparable measures of a quantity, or
- the difference between computed values of a quantity obtained by different processes in the same survey.

Displacement, height. Displacement of images radially inward or outward with respect to the photograph nadir, depending on whether the ground objects are, respectively, below or above the elevation of the ground nadir.

Displacement, relief. Displacement of images radially inward or outward from the nadir point of the photograph. Relief displacement of images is caused by differences in elevation of the corresponding ground objects whether below or above, respectively, the elevation of the ground nadir.

Displacement, tilt. Displacement of images on a tilted photograph radial from its isocenter. Tilt displacement is outward or inward with respect to the isocenter, according to whether the images are on the low or high side of the isometric parallel (the low side is the closest to the earth, or the object plane).

Distortion. Any shift in the position of an image on a photograph that alters the perspective characteristics of the photograph. Causes of image distortion include lens aberration, differential shrinkage of film or paper, and motion of the film or camera.

Dog-leg point. A survey station that has no check.

Double centering. A method of prolonging a line from a fixed point whereby the backsight is taken with the telescope in the direct position. The telescope is placed in the inverted position and the foresight is made. The point at which the vertical cross hair intersects the hub is then marked. The transit is then rotated 180 degrees to take a backsight with the telescope in the inverted position, and a second projected point with the telescope in the direct position is marked on the hub. A point midway between the two marked points is the true point on the prolonged line.

Double meridian distance. The sum of the meridian distances of the ends of a survey line. In practice, assuming a closed traverse with the meridian of reference passing through the initial station, the double meridian distance (DMD) of the first course (line) is equal to the departure of the course; the double meridian distance of each succeeding course (line) is equal to the double meridian distance of the preceding course, plus the departure of the preceding course, plus the departure of the course itself.

If the DMD of each course is multiplied by the latitude of the corresponding course, double areas are obtained, from which the area of the tract can be obtained. By a strictly analogous procedure, double parallel distances (DPD) can be computed, using the latitudes of the successive courses instead of departures and using an east-west line as the reference parallel.

Double proportionate measurement. A method for restoring a lost corner of four townships or a lost interior corner of four sections. It is based on the principle that monuments north and south should control the latitudinal position of a lost corner, and monuments east and west should control the longitudinal position. In this method, the influence of one identified original corner is balanced by the control of a corresponding original corner upon the opposite side of a particular missing corner, which is to be restored, each identified original corner being given a controlling weight inversely proportional to its distance from the lost corner.

E

Easting. A linear distance eastward from the north-south line that passes through the origin (or false origin) of a grid. Generally, the false origin is selected so that the opposite term, i.e., westing, does not exist in the project survey coordinate system. Same as x-coordinate.

Elevation. The vertical distance from a datum, generally mean sea level, to a point or object on the earth's surface.

Emulsion (photography). A suspension of a light-sensitive silver salt (especially silver chloride or silver bromide) in a colloidal medium (usually gelatin) which is used for coating photographic films, plates, and papers. Types of photographic emulsions currently in common usage are panchromatic (black and white), color negative, color positive, infrared color, and infrared black and white.

Ephemeris.

- A publication giving coordinates of celestial bodies at uniform time intervals; the coordinates are usually given for one calendar year. A publication giving similar information in a form suitable for use by a navigator is called an almanac.
- An ephemeris is also a statement, not necessarily in a publication, presenting a correlation of time and position of celestial bodies.

Error of closure. The amount by which the value of a quantity obtained by surveying operations fails to agree with another value of the same quantity held fixed from earlier determinations or with a theoretical value of the quantity.

Extrapolation. The process of estimating the value of a quantity beyond the limits of known values by assuming that the rate of change between the last few known values continues.

Eye Base. The interpupillary distance between the eyes of an individual.

F

Falling. The distance on the normal by which a random line falls to the right or left of a corner.

Fiducial marks (photogrammetry). Index marks, at least four, rigidly connected with the camera lens through the camera body and forming images on the negative that generally define the principal point of the photograph. Also, those marks, usually four in number, in any instrument that define the axes whose intersections fix the principal point of a photograph or negative and fulfill the requirements of interior orientation.

Field inspection (photogrammetry). The process of comparing aerial photographs with conditions as they exist on the ground and of obtaining information to supplement or clarify that which is not readily discernible on the photographs themselves.

Fixed-end traverse. A traverse that starts on one point and ends at another with both points being held and the new data adjusted between them.

Flight line. A line drawn on a map or chart to represent the track of the aircraft during the period of taking aerial photographs.

Flight map. The map on which are indicated the desired lines of flight and the position of exposure previous to the taking of air photographs, or the map on which are plotted, after photography, selected air stations and the tracks between them.

Flight strip. A succession of overlapping aerial photographs taken along a single course.

Focal length. A general term for the distance between the center, vertex, or rear node of a lens (or the vertex of a mirror) and the point at which the image of an infinitely distant object comes into critical focus. The term must be preceded by an adjective such as "equivalent" or "calibrated" to have precise meaning.

Foresight.

- A point to which an instrument sighting is made for measuring or establishing its elevation and/or its horizontal positions.
- For leveling, the foresight is the visual intersection of the horizontal cross hair of the instrument with the foresight point or with a staff or rod held vertically over or under the foresight point when the instrument line of sight is level or when the vertical angle of the instrument line of sight is known or will become known from actual measurement.
- For angle measuring or line prolongation, the foresight is the angle measurement on the graduated horizontal circle of the instrument (set or to be read and recorded) when the vertical cross hair of the instrument visually coincides with the foresight point or with a marker in the vertical plane through the foresight point and the center of the instrument.

G

Gap (aerial photography). Any space between aerial photographs failing to meet minimum ground coverage requirements. The gap may be space not covered by any photograph in line of flight or between separate flights, or the space where specified endlap or sidelap was not obtained. Also called "hiatus."

General Land Office. Formerly an office of the United States government, being a division of the Department of the Interior, having charge of all executive action relating to the public lands, including their survey, sale or other disposition, and patenting; originally constituted by Act of Congress in 1812. The General Land Office and the US Grazing Service were consolidated into the Bureau of Land Management under the Department of the Interior by the 1946 Reorganization Plan No. 3, 403.

Geographic (geographical). Signifying basic relationship to the earth considered as a globe-shaped body. The term geographic is applied alike to data based on the geoid and on the spheroid. In geodetic surveys in the United States, coordinated data consisting of latitudes, longitudes, azimuths, and lengths of lines are recorded and published under the general title of "geographic positions."

Grid. A network composed of two sets of lines, each set drawn according to a definite pattern and intersecting the other in a specific geometric arrangement. The most common form of grid consists of uniformly spaced parallel lines intersecting at right angles. The term is frequently used to designate a plane-rectangular coordinate system superimposed on a map projection, in which case it generally carries the name of the projection; that is "Lambert grid," "Transverse Mercator grid," "Universal Transverse Mercator grid." Also the system of points or lines for which field measurements are made, or for which computations are made to serve as a basic control system for measuring.

Grid azimuth. An azimuth measured from grid north.

Grid coordinates. The X and Y that designates a point on a grid.

Grid factor. A scale factor used to convert from sea level distance to grid distance, or vice versa, in the state coordinate systems.

Grid length. The distance between two points as obtained by computation from the plane-rectangular coordinates of the points. In the state coordinate systems, a grid length differs from a geodetic length by the amount of a correction based on a scale and elevation factor for a given line.

Grid tick. A small mark placed at the edge of a map or drawing to indicate a measurement. The grid system used may be indicated by ticks for future reference.

Gross model. Total area covered by the overlap of two consecutive aerial photos.

Ground control. In photomapping, control obtained from surveys as distinguished from control obtained by photogrammetric methods.

Guard stake. A stake driven near (within 6 inches) a hub, usually sloped with the top driven to clear the hub. The guard stake protects the hub and the markings on the stake identify it.

H

Height of instrument.

- The height of the center of the telescope (horizontal axis) above the ground or station mark.
- (Leveling) The height of the line of sight of the leveling instrument above the adopted datum.

Height of signal. Height of signal is measured from the top of the control point to the center of the instrument used to measure the zenith angle.

Heliotrope. A device used in geodetic surveying for reflecting the sun's rays to a distant point, to aid in long-distance observations. A similar device for reflecting the moon's rays is called a selenotrope.

Horizon, apparent (visible). The irregular line along which rays from the point of observation are tangent to the surface of the earth. The apparent horizon is the line where the visible surface of the earth appears to meet the sky. When the apparent horizon is formed by the surface of a body of water, it is sometimes used as a reference in observing vertical angles.

Horizon, closing the. Measuring the last of a series of horizontal angles at a station required to make the series complete around the horizon. At any station, the sum of all horizontal angles between adjacent lines should equal 360 degrees. The amount by which the sum of the measured angles fails to equal 360 degrees is the error of closure. This error is distributed as a correction for closure among the measured angles to bring their sum to exactly 360 degrees. The error and the correction are of opposite signs.

Horizontal angle. An angle measured in a horizontal plane.

Horizontal axis (theodolite or transit). The axis about which the telescope of a theodolite or transit rotates when moved vertically. It is the axis of rotation that is perpendicular to the vertical axis of the instrument and to the axis of the collimation of the telescope. It should coincide with the line through the centers of the pivots that support the telescope. For an instrument in complete adjustment, it occupies a horizontal position, and when the telescope is rotated around it, the axis of collimation will define the vertical plane; deviations from this condition are measured with a striding level or with a hanging level.

Horizontal control. Control stations whose coordinates are known.

Horizontal datum. In plane surveying, the grid system of reference used for the horizontal control of an area; defined by the easting and northing of one station in the area, and the azimuth from this selected station to an adjacent station.

Horizontal direction. A direction in a horizontal plane.

Horizontal distance. The distance measured in a horizontal plane, as distinguished from a distance measured on a slope. Horizontal distance refers primarily to taped distances, either measured horizontally or reduced to horizontal distances by computations.

Horizontal plane. A plane perpendicular to the direction of gravity.

Horizontal position. The grid position of a horizontal control point.

Horizontal and vertical control point. When used in aerial photo work, it refers to a photo image point that has X, Y and Z coordinate values. These image points are used to control the scale and elevation of stereo models in the preparation of topographic maps.

Hub. A wooden stake or pipe set in the ground, with a tack or other marker to indicate the exact position. A guard stake protects and identifies the hub.

I

Intersection. A method of locating the horizontal position of a point by observations from two or more points of known position, thus measuring directions that intersect at the station being located. A station whose horizontal position is located by intersection is known as an intersection station.

Instrument direct. The theodolite or engineer transit in its normal position. In field notes, D signifies a reading with the instrument direct, called a "direct reading."

Instrument reversed or inverted. The theodolite or engineer transit when the telescope is plunged from the instrument direct position. In field notes, R signifies a reading with the instrument reversed, called a "reversed reading."

Inverse computation. The computation for the length and azimuth of a line from the coordinates of its endpoints. This is the inverse of the more common survey computation in which the position of a new station is determined through the length and azimuth of the connecting line.

L

Latitude. Angular distance measured on a meridian, north or south from the equator. The length of a degree of latitude varies because of the flattened figure of the earth, being 68.704 statute miles at the equator and 69.407 at the poles.

Latitude (plane surveying). The orthographic projection of a course upon the north-south axis of the survey. It is equal to the length of the course multiplied by the cosine of the bearing.

Level.

- Pertaining to a level surface.
- To make horizontal at the point of observation.
- An instrument for leveling.

Level circuit. The measurement of bench mark elevations by spirit leveling in two different directions from one end of the circuit to another. Different turning points are used in each of the two different directions.

Level circuit, multiple. More than two measurements of elevation by spirit leveling along different routes between the same terminal points.

Level circuit, simultaneous. The circuit of spirit levels measured between two terminal points composed of two separate turning points for computing the height of instrument at each successive setup. Also termed "double rodded level circuit."

Level datum. A level surface to which elevations are referred. The generally adopted level datum for leveling in the United States is mean sea level. For local surveys an arbitrary level datum is often adopted and defined in terms of an assumed elevation for some physical mark (bench mark).

Level line.

- A line in a horizontal plane, or
- A line over which leveling operations are accomplished.

Level net. Lines of spirit leveling connected together to form a system of loops or circuits extending over an area. Also called a vertical control net.

Level surface. A horizontal plane.

Leveling. The operation of measuring vertical distances, directly or indirectly, to determine elevations.

Leveling, differential. The process of measuring the difference of elevation between any two points by spirit leveling.

Leveling, fly.

- The extension of a level circuit at the close of a working day to check the results of a level circuit measured in one direction only.
- Level circuits measured with the engineer's ordinary leveling equipment but with a distinctly low order of accuracy. The error of closure may be perhaps 1 foot (or more) times the square root of the distance in miles, thus permitting long sights and rapid progress.

Leveling, geodetic. Spirit leveling of a high order of accuracy, usually extended over large areas, to furnish accurate vertical control as a basis for the control in the vertical dimension for all surveying and mapping operations.

Leveling, indirect. The determination of differences of elevation from vertical angles and slope distances, as in "trigonometric leveling."

Leveling, reciprocal. A procedure of measuring vertical angles or making rod readings from two instrument positions for the purpose of compensating for earth curvature, the effects of atmospheric refraction and some instrument misadjustments.

Leveling, spirit. The determination of elevations by use of a leveling rod and an instrument using a spirit level to establish a horizontal line of sight; the term has now been broadened to include leveling by means of other types of precise levels, such as a pendulum level.

Leveling, trigonometric. The determination of differences of elevation trigonometrically from observed vertical angles and measured or computed horizontal or inclined distances.

Leveling rod. A straight rod or bar with a flat face graduated in linear units with zero at the bottom, used in measuring the vertical distance between a point on the ground (or other fixed location) and the horizontal line of sight of a leveling instrument. Rods are usually made of wood or metal. For more accurate leveling, the graduations are placed on an invar strip fastened to the foot of the rod and held against the face of the rod to maintain a constant tension in the invar strip. A self-reading rod is designed to be read by the observer at the leveling instrument. A

target rod has a movable target that is raised or lowered by the rodperson in response to signals from the instrument operator; the position of the target on the rod is then read with the aid of a vernier.

Line, base (USPLS). A line extending east and west along the astronomic parallel passing through the initial point, along which standard township, section, and quarter-section corners are established. As may be inferred from its designation, the base line is the line from which is initiated the survey of the meridianal township boundaries and section lines. Auxiliary governing lines, known as standard parallels or correction lines, are established along astronomic parallels usually at intervals of 24 miles north or south of the base line. In some of the early surveys, the base line was referred to as the "basis parallel."

Line, center. Applied to a street, right of way, or any other strip of land of uniform width; defines the line midway between the side lines of said strip.

Line, contour. An imaginary line connecting the points on a land surface that have the same elevation; also, the line representing this on a map or chart.

Line, cut-off. A survey line run between two or more stations on a traverse for the purpose of producing a closed traverse of that part of the survey.

Line, grade. The slope in the longitudinal direction of the roadbed, usually expressed as a percentage which is the number of units of change in elevation per 100 units horizontal distance. Also has a "general" use to mean the "highway profile."

Line, random. A trial line, directed as closely as possible toward a fixed terminal point that is not visible from the initial point. The error of closure (amount by which the second station is missed) permits the computation of a correction to the initial azimuth of the random line; it also permits the computation of offsets from the random line to establish points on the line between the survey stations.

Locative calls. In descriptions of land, locative calls are specific calls to determine location. In harmonizing conflicting calls in a deed or survey of lands, courts will ascertain which calls are locative and which are merely directory, and conform the lines to the locative calls; directory calls being those which merely direct to a neighborhood where the definite calls may be found, whereas locative calls fix boundaries.

Longitude. The angle between the plane of a given meridian and the plane of an arbitrary initial meridian, generally the meridian of Greenwich. It may be measured as the angle at the poles between the two meridians, as the arc of the equator intercepted between the meridians, or as the arc of a parallel of latitude intercepted between the meridians.

Loop traverse. A closed traverse that starts and ends at the same station.

M

Magazine (photography). A container for rolled film or photographic plates attached to the camera body and usually equipped with automatic mechanisms to advance and position the photographic material for exposure.

Magnetic azimuth. An azimuth measured with reference to the direction indicated by a magnetic compass needle. Magnetic azimuth is measured from magnetic north, which is east or west of true north as shown by the magnetic declination.

Magnetic declination. The angular amount that a magnetic compass needle points eastward or westward from true north. For this purpose, either astronomic north or geodetic north is considered as true north.

Magnetic variation. Regular or irregular changes in the magnetic declination with time.

Main-scheme station. A station through which the main computations and adjustments of the survey data are carried. Also called a principal station, the main-scheme stations serve for the continued extension of the survey.

Map. A representation on a plane surface, at an established scale, of the physical features (natural, artificial, or both) of a part or the whole of the earth's surface, by the use of signs and symbols, and with the method of orientation indicated. Also, a similar representation of the heavenly bodies. A map may emphasize, generalize, or omit the representation of certain features to satisfy specific requirements. The type of information which a map is designed primarily to convey is frequently used, in adjective form, to distinguish it from maps of other types. A map should contain a record of the projection upon which it is constructed.

Map, base.

- A map showing certain fundamental information, copies of which are used to compile additional data of specialized nature. Often used to define a large-scale planimetric map compiled from aerial photographs, copies of which are used for the addition of contours and other data by use of the plane table and photogrammetric methods.
- A map containing all the information from which maps showing specialized information can be prepared; a master map.

Map, cadastral. A map showing the boundaries of subdivisions of land, usually with the bearings and lengths thereof and the areas of individual tracts, for purposes of describing and recording ownership. A cadastral map may also show culture, drainage, and other features relating to the value and use of land.

Map, contour. A map that portrays the elevation and configurations of the ground by contour lines, and lacks any other details except notations and contour elevations.

Map, engineering. A map showing information that is essential for planning an engineering project or development and for estimating its cost. An engineering map is usually a large-scale map of a comparatively small area or of a route. It may be entirely the product of an engineering survey, or reliable information may be collected from various sources for the purpose and assembled on a base map.

Map, highway. A map containing the planimetric configurations of a highway and its connections, at grade or by controlled access, to other highways; also a map containing the details of curvature, roadside and cross drainage, right-of-way boundaries, and delineations regarding adjacent occupancy and land uses. The detail in a highway map is dependent entirely upon its scale and the purpose of its use whether for merely indicating travel routes or for depicting construction details.

Map, manuscript. The original drawing of a map.

Map, planimetric. A map that presents only the horizontal positions for the features represented.

Map, projection, Transverse Mercator. A map projection of the so-called cylindrical type, being in principle equivalent to the regular Mercator map projection turned (transversed) 90 degrees in azimuth. In this projection, the central meridian is represented by a straight line, corresponding

to the line that represents the equator on the regular Mercator map projection. Neither the geographic meridians, except the central meridian, nor the geodetic parallels, except the equator (if shown) are represented by straight lines. It is a conformal projection and is the base used in the state plane coordinate systems for the grids of those zones whose greater dimension is in a north and south direction.

Map scale. The relationship existing between a distance on a map and the corresponding distance on the earth. Map scale may be expressed as an equivalence, usually by different units, that is, 1 inch = 1 mile, as a numerical fraction or ratio (1/63,360 or 1:63,360), or graphically, by a bar scale. Fractional map scale is representative in any linear units, and is often called the representative fraction, or R.F., when the numerator is unity.

Map scale, graphic (or bar). A line on a map subdivided and marked with the distance which each of its parts represents on the earth.

Map, topographic. A map that presents the horizontal and vertical positions of the features represented; distinguished from a planimetric map by the addition of relief in measurable form. A topographic map usually shows the same features as a planimetric map but uses contours or comparable symbols to show mountains, valleys, and plains; and in the case of hydrographic charts, symbols and numbers to show depths in bodies of water.

Mark.

- "Now" or "at this moment." A call used when simultaneous observations are being made, to indicate to the second person the moment a reading is to be made, as when the time of a celestial observation is to be noted; or the moment a reading is a prescribed value.
- A definite object (such as an imprinted metal disk) used to designate a survey point. Usually used with a qualifying term such as station mark, reference mark, azimuth mark, or bench mark. Sometimes refers to the entire survey monument.

Mass diagram. The earthwork mass diagram is a continuous graph of net cumulative yardage at any point on an earthwork project. It is used to analyze amounts of excavation and embankment, balance points, and haul requirements.

Mean sea level (MSL). The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings. A determination of mean sea level that has been adopted as a standard for heights is called a sea level datum. The sea level datum now used for the National Ocean Survey level net is officially known as the Sea Level Datum of 1929, the year referring to the last general adjustment of the net, and is based upon observations taken over a number of years at various tide stations along the coasts of the United States and Canada.

Memorial (USPLS). A durable article deposited in the ground at the position of a corner to perpetuate that position should the monument be removed or destroyed. The memorial is usually deposited at the base of the monument and may consist of anything durable, such as glass or stoneware, a marked stone, charred stake, or a quantity of charcoal.

Meridian. A north-south line from which longitudes (or departures) and azimuths are reckoned.

Meridian, central.

- The line of longitude at the center of a projection. Generally the basis for constructing the projection.

- The longitude of origin at the center of each zone of the Transverse Mercator grid. The central meridian is arbitrarily numbered 500,000 and is called a false easting.
- (State plane coordinate system) The meridian used as the y-axis for computing projection tables for a state coordinate system. The central meridian of the system usually passes close to the center of figure of the area or zones for which the tables are computed.

Metes and bounds. A method of describing land by measure of length (metes) or the boundary lines (bounds). The most common method is to recite direction and length of each line as one would walk around the perimeter. In general, the "metes" and "bounds" can be recited by reference to record, natural or artificial monuments at the corners; and record, natural or cultural boundary lines. See also "Description, metes and bounds."

Monument (USPLS). A physical structure that marks the location of a corner or other survey point. In public-land surveys, the term "corner" is employed to denote a point determined by the surveying process, whereas the "monument" is the physical structure erected to mark the corner point upon the earth's surface. Monument and corner are not synonymous, though the two terms are often used in the same sense.

Monument, record. An adjoiner property called for in a deed such as a street or particular parcel of land. Frequently the boundary line of the adjoiner is referred to as the record monument; actually the entire property, rather than the line, is the monument. Physical monuments may or may not mark a record monument.

Mosaic, photographic. An assembly of aerial photographs whose edges usually have been torn or cut and matched to form a continuous photographic representation of a portion of the earth's surface. Often called an aerial mosaic. "Controlled mosaic" — a mosaic oriented and scaled to horizontal ground control; usually assembled from rectified photographs. "Uncontrolled mosaic" — a mosaic in which the photographs have not been adjusted by the reference to ground control.

Most probable value. That value of a quantity that is mathematically determined from a series of observations and is more nearly free from the effects of blunders and errors than any other value that might be derived from the same series of observations.

N

Nadir. The point on the celestial sphere directly beneath the observer, and directly opposite the zenith.

Neat model. That portion of a stereoscopic model, considered most free of lens distortion and within which all ground control stations are located.

Normal. In general, a straight line perpendicular to a surface or to another line. Also, a condition of being perpendicular to a surface or line. In geodesy, a straight line perpendicular to the surface of the spheroid.

North. The primary reference direction relative to the earth; the direction indicated by 000 degrees in any system other than relative. True north is the direction of the north geographical pole; magnetic north, the direction north as determined by the earth's magnetic lines of force; compass north, the direction north as indicated by a magnetic compass; grid north, an arbitrary reference direction used with grid navigation.

North, magnetic. The direction of the north-seeking end of a magnetic compass needle not subject to transient or local disturbance.

North, true. A term used to define:

- as astronomic meridian,
- a geodetic meridian,
- the direction of north from magnetic north corrected for declination,
- the meridianal direction assumed in a survey description, or
- the cardinal directions run in the Public Land Survey.

Because the term is subject to several interpretations, it should not be used.

North point. An arrow-like symbol indicating the direction and the type of meridian to which the control framework of a map or drawing is referenced. Auxiliary arrows may be shown indicating the direction of other meridians that may be of interest to the user of the map. A star often is used to indicate astronomic north, a full barb to indicate grid north, and a half-barb to indicate magnetic north. Where magnetic meridians are shown, the date and declination from astronomic north should be indicated.

Northing. A linear distance northward from the east-west line that passes through the origin (or false origin) of a grid. Generally the false origin is selected so that all northings remain positive. Same as y-coordinate.

O

Objective. The lens in a microscope or telescope that is nearest the object. Also the lens used in a camera.

Oblique photograph. A high oblique includes the horizon while a low oblique does not. A photograph taken with the camera axis intentionally directed between the horizontal and the vertical.

Observation. Act of recognizing and noting some fact or occurrence, especially in nature, often involving the measurement of some magnitude with suitable instruments.

Observation, direct. A measure of the quantity whose value is desired. Example: a single measure of a horizontal angle.

Observation, indirect. A measure of a quantity that is a function of the quantity or quantities whose value is desired. Example: an observed difference of elevation with a spirit level, used to obtain the elevation of a bench mark.

Observed value. A value of a quantity that is obtained by instrumental measurement of the quantity. The term "observed value" is often applied to the value of a quantity derived from instrumental measurement after corrections have been applied for systematic errors, but before accidental errors have been taken out by some method of adjustment. See also "Most probable value."

Occupied station. A traverse or triangulation station over which a theodolite or an engineer transit is set up for the measurement of angles at this station. Also, a station at which angles have been so measured.

Offset line. A supplementary line close to, and usually parallel to, a main survey line to which it is referenced by measured offsets. When the line for which data are desired is in such position that it is difficult to measure over it, the required data are obtained by running an offset line in a convenient location and measuring offset from it to salient points on the other line.

Open traverse. A traverse that starts at a point of known or assumed position, and ends at a point whose relative position is unknown with respect to the starting point.

Optical targets. Precision sighting devices used with theodolites and total stations.

Order of accuracy. A mathematical ratio defining the general accuracy of the measurements made in a survey. The orders of accuracy for surveys are divided into four classes named first order, second order, third order and fourth order.

Orientation. The act of establishing the correct relationship in direction with reference to the points of the compass; the state of being in correct relationship in direction with reference to the points on a compass.

A map is in orientation when the map symbols are parallel with their corresponding ground features.

A plane table is in orientation when lines connecting positions on the plane table sheet are parallel with the lines connecting the corresponding ground objects.

A surveyor's transit is in orientation if the horizontal circle reads 0 degrees when the line of collimation is parallel to the direction it had at an earlier (initial) position of the instrument, or to a standard line of reference. If the line of reference is a meridian, the circle will show azimuths referred to that meridian.

A photograph is in orientation when it correctly presents the perspective view of the ground directly in front of the observer; or when the images on the photograph appear in the same direction from the point of observation as do the corresponding map symbols.

Overlap.

- The amount by which one photograph includes the same area as covered by another, customarily expressed as a percentage.
- That area of a map or chart which overlaps the same geographical area on an adjoining map or chart.
- An area included within two surveys of record, which by the record is described as having one or more common boundary lines with no inclusion of identical parts.

Overlapping pair (photogrammetry). Two photographs taken at different exposure stations in such a manner that a part of one photograph shows the same terrain as shown on a part of the other photograph. This term covers the general case and does not imply that the photographs were taken for stereoscopic examination. See also "Stereoscopy."

Overlay (mapping). A record on a transparent medium to be superimposed on another record. For example, maps showing original land grants (or patents) prepared as tracing-cloth overlays in order that they can be correlated with the maps showing present ownership. Also, any of the several overlays that may be prepared in compiling a manuscript map, usually described by name, for example, lettering overlay.

Ownership. State, relation, or fact of being an owner; lawful claim or title; property; proprietorship; dominion. All ownership is by purchase or descent.

P

Pantograph. An instrument for copying maps, drawings, or the like at a predetermined reduction or enlargement. It generally consists of four bars hinged to form a parallelogram linkage, so

designed and proportioned that when the frame is pinned to a base at one point, the motion of an attached pencil is proportional to the motion of a tracing stylus; the pivot, pencil, and stylus always being maintained on line by the linkage arrangement. In a variable-ratio pantograph, two or more of the hinges are movable so that the relative lengths of the bars forming the parallelogram may be adjusted to vary the scale or reduction or enlargement within wide limits; in a fixed-ratio pantograph the effective lengths of the bars remain fixed so that reductions can be made at only one scale ratio, or enlargements at the reciprocal of that ratio. When used as an accessory to a photogrammetric instrument, the pantograph is an instrument for compiling maps at a scale equal to, or different from, the stereoscopic model.

Parallax. The apparent displacement of the position of any point with respect to a reference point or system, caused by a shift in the station of observation. The parallax of one point in space in respect to a reference point is the angle of convergence of the rays from two observation stations to the reference point, minus the angle of convergence of the rays from the same two observation stations to the second point. On a pair of photographs of the points in space taken from the two observation stations, parallax is measured by distances on the photographs rather than by angles.

Parallax, instrumental. A change in the apparent position of an object with respect to the reference marks of an instrument which is due to imperfect adjustment of the instrument, to a change in the position of the observer, or both.

Parallel, geographic. A line on the earth having the same latitude at every point. The term is applicable alike to an astronomic parallel or to a geodetic parallel.

Parallel, standard (USPLS). An auxiliary governing line established along the astronomic parallel, initiated at a selected township corner on a principal meridian, usually at intervals of 24 miles from the base line, on which standard township, section, and quarter-section corners are established; also termed a correction line. These lines were established to limit the convergence or range lines from the south. In many of the surveys made before 1850, standard parallels or correction lines were run distances of 30, 36, and sometimes even 60 miles apart from the base line.

Parol.

- Pleading; the pleadings of either or both parties in an action.
- Executed or made by word of mouth, or by a writing not under seal.

Parol agreement. An oral agreement between the owners establishing the boundaries dividing adjacent land.

Parol evidence. Oral evidence; that which is given by word of mouth; the ordinary kind of evidence, given by witnesses in court. In a particular sense, and with reference to contracts, deeds, wills, and other writings, parol evidence is the same as extraneous evidence or evidence aliunde.

Pass point. A natural image or marked point visible on a photograph for which the horizontal position and/or elevation has been or will be determined by photogrammetric use of the photograph and its stereoscopically adjacent photographs. A pass point is used for the orientation of photographs in photogrammetric instruments in the same manner in which supplemental control points are used.

Permanent survey station (or permanent marker). A 5/8-inch smooth bar with aluminum cap stamped with identification code, and set within a six-inch collar of concrete.

Semi-permanent survey station (or semi-permanent marker). Same as permanent marker, above, but without concrete collar.

Perpendicular. A perpendicular line, plane, etc. A distinction is sometimes made between perpendicular and normal, the former applying to a line at right angles to a straight line or place, and the latter referring to a line at right angles to a curve or curved surface.

Phase. The visible aspect of an object. The apparent displacement of an object or signal caused by one side being more strongly illuminated than the other. The resultant error in pointing is similar to the error caused by observing an eccentric signal.

Phase of target (error caused by). Uneven illumination of target causing error in sighting.

Photo I.D. The photo identification point is a photo image point that is visible on the photograph and can be identified on the ground. Photo I.D. points can be pre-marked (targeted) points, but more commonly they are definable physical features. The term is generally used to refer to photo image points that are used to supplement control after photos have been taken.

Photogrammetry. The science or art of obtaining reliable measurements by photography. "Aerial photogrammetry" — photogrammetry with the aid of aerial photographs. "Terrestrial photogrammetry" — photogrammetry with the aid of ground photographs. Also termed ground photogrammetry, although this term is not preferred. "Stereophotogrammetry" — photogrammetry with the aid of stereoscopic equipment and methods. See also "Aerial photography."

Photograph. A general term applying to either a positive or a negative exposed on light sensitized material by use of a camera. Also the print made photographically from the negative or positive. The photograph may be exposed or printed, using any one of these types of emulsions: panchromatic, negative or positive color, infrared color, or infrared black and white.

Photograph center. The center of a photograph as indicated by the images of the fiducial mark or marks of the camera. In a perfectly adjusted camera the photograph center and the principal point are identical.

Photographic interpretation. The determination of the nature and description of objects that are imaged on a photograph.

Phototriangulation. The process for the extension of horizontal and/or vertical control whereby the measurements of angles and/or distances on overlapping photographs are related into a spatial solution using the perspective principals of the photographs. Generally, this process involves using aerial photographs and is called aerotriangulation or aerial triangulation.

Phototriangulation, analytical. A phototriangulation procedure in which the spatial solution is obtained by computational routines. When performed with aerial photographs, the procedure is referred to as analytical triangulation.

Picture point. In surveying, a terrain feature that is easily defined on an aerial photograph, and whose horizontal or vertical position has been determined by survey measurements. Picture points are marked on the aerial photographs by the surveyor and are used by the photomapper.

Pier. An intermediate support for the adjacent ends of two bridge spans.

Plane coordinates. See "Grid coordinates."

Plane survey. A survey in which the effect of the curvature of the earth is almost entirely neglected, and computations of the relative positions of the stations are made using the principles of plane geometry and plane trigonometry.

Plat (USPLS). The term "plat," as employed technically by the US Bureau of Land Management, refers to the drawing that represents the particular area included in a survey, such as a township,

private land claim, or mineral claim, and the lines surveyed, established, retraced, or resurveyed, showing the direction and length of each line; the relation to the adjoining official surveys; the boundaries, descriptions, and area of each parcel of land subdivided; and, as nearly as may be practicable, a representation of the relief, and improvements within the limits of the survey.

Plat, supplemental (USPLS). A plat prepared entirely from office records designed to show a revised subdivision of one or more sections without change in the section boundaries and without other modification of the subsisting record. Supplemental plats are required where the subsisting plat fails to provide units suitable for administration or disposal, or where a modification of its showing is necessary. They are also required to show the segregation of alienated lands from public lands, where the former are included in irregular surveys of patented mineral or other private claims made subsequent to the plat of the subsisting survey, or where the segregation of the claims was overlooked at the time of its approval.

Plumb bob. A conical device, usually of brass and suspended by a cord, by means of which a point can be projected vertically into space over relatively short distances.

Plus distance. The distance along a survey line from a survey station or the last even-numbered survey point to a supplementary point. A stake is set at 515.55 feet from the initial point of a survey line and is not the terminal of that line; the even 500-foot point is station No. 5; the stake is a plus station (No. 5+15.55), and 15.55 feet is a plus distance.

Plus point. An intermediate point on a traverse course located by a plus distance from the beginning of the course.

Pointers. The second-magnitude stars, Alpha and Beta, in the constellation Ursa Major (Big Dipper), the line through which points to Polaris. The points facilitate the finding and identification of Polaris. They are in the outer side of the "bowl" of the Big Dipper, away from the handle.

Point of vertical curve (P.V.C.). The point of change from a line of uniform slope to a vertical curve.

Point of vertical intersection (P.V.I.). The point of intersection of two lines, each having different uniform slope.

Point of vertical tangent (P.V.T.). The point of change from a vertical curve to a line of uniform slope.

Point-transfer device. A stereoscopic instrument used to mark corresponding image points on overlapping photographs.

Polaris. The second-magnitude star, Alpha, in the constellation Ursa Minor (Little Dipper). Also known as the polestar, or north star, because of its proximity to the north pole of the celestial sphere. Polaris is well situated for determinations of astronomical azimuth, and for the determination of the direction of the celestial meridian. It is at the extreme outer end of the handle of the "Little Dipper." See also "Pointers."

Polar survey. The turning of angles and measurement of distances from a principal control point to a series of additional control points, with the position of each point determined independent of the others.

Pole, magnetic. Either of the poles of a magnet; specifically either of two spots on the earth's surface, toward which the compass needle points from any direction throughout adjacent regions, and at which the needle dips vertically. These spots are known respectively as the North (approximately North latitude 73 degrees 35 minutes, West longitude 92 degrees 20 minutes) and

the South (approximately South latitude 70 degrees, East longitude 148 degrees). Isogonic lines converge at them and isoclinic lines encircle them.

Position.

- Data that define the location of a point with respect to a reference system.
- The place occupied by a point on the surface of the earth.
- The coordinates that define the location of a point on the geoid or spheroid.
- A prescribed setting (reading) of the horizontal circle of a direction theodolite that is to be used for the observation on the initial station of a series of stations to be observed.

Position, astronomical.

- A point on the earth whose coordinates have been determined as a result of observations of celestial bodies. The expression is usually used in connection with positions on land determined with great accuracy for survey purposes.
- A point on the earth, defined in terms of astronomical latitude and longitude.

Position, field. A position computed while field work is in progress to determine the acceptability of the observations or to provide a preliminary position for other purposes.

Position, geodetic. A position of a point on the surface of the earth expressed in terms of geodetic latitude and geodetic longitude. A geodetic position implies an adopted geodetic datum. In a complete record of a geodetic position, the datum must be stated.

Position, geographic. The position of a point on the surface of the earth expressed in terms of latitude and longitude, either geodetic or astronomic.

Position error.

- The error of a position.
- That error of an instrument reading due to location or orientation.

Positional error (cartography). The amount by which a cartographic feature fails to agree with its true position.

Positive (photography). A photograph having approximately the same rendition of light and shade as the original subject. A print from a negative.

Power of telescope. The magnification of a telescope when focused for infinite sights.

Precision. The degree of refinement in the performance of an operation, or the degree of perfection in the instruments and methods used when making the measurements. A measure of the uniformity or reproducibility of the result. Precision relates to the quality of the operation by which a result is obtained, and is distinguished from accuracy which relates to the quality of the result.

Pressure plate (photography). A flat plate, usually of metal but frequently of glass or other substance, which by the use of mechanical force, presses the film into contact with the focal plane of the camera.

Prima facie evidence. Evidence deemed by law to be sufficient to establish a fact if the evidence is not disputed.

Print (photography). A photographic copy made by projection or contact printing from a photographic negative or from a transparent drawing, as in blueprinting. "Contact print" — a print

made with the negative or transparent drawing in contact with the sensitized surface. "Ratio print" — a print, the scale of which has been changed from that of the negative by enlargement or reduction.

Profile. A vertical section of the surface of the ground, or of underlying strata, or both, along any fixed line.

Profile, ground. A line indicating ground elevations of a vertical section along a survey line.

Profile grade. The trace of a vertical plane intersecting the top surface of the proposed wearing surface, usually along the longitudinal center line of the roadbed. "Profile grade" means either elevation or gradient of such trace according to the context.

Progress sketch. A map or sketch showing work accomplished. In triangulation and traverse surveys, each point that is established is shown on the progress sketch as well as lines observed over and base lines measured. In a leveling survey, the progress sketch shows the route followed and the towns passed through, but not necessarily the locations of the bench marks.

Project. A definite undertaking, usually with definite limits and specifications or standards.

Projection. The extension of a line beyond the points that determine its character and position. The transfer of a series of survey lines to a single theoretical line by a series of lines perpendicular to the theoretical line. In surveying a traverse, a series of measured short lines may be projected onto a single long line, connecting two main survey stations, and the long line is then treated as a measured line of the traverse.

Prolong. To lengthen in extent or range; as to prolong a line.

Prolongation. With reference to a line it is used to indicate the continuity in the same direction of the recited course that is to be lengthened. A line is prolonged, but a curve is continued. A "prolongation" of a curve is the extension of the tangent to the curve, and should not be used in referring to curve continuation. The prolongation of a line, composed of several parts of different directional values, is the prolongation of the course nearest to the recited intersection or monument.

Proportionate measurement. A measurement that applies an even distribution of a determined excess or deficiency of measurement, ascertained by retracement of an established line, to provide concordant relations between all parts.

Proportioning excess or deficiency (principle of). A principle, governed by several rules, of distributing excess or deficiency. For example, the frontage of 10 lots in a city block may total 1,000 feet by deed or plan. The measured length of the block is 1,007.42 feet. Where the principle applies, the excess, 7.42 feet, must be distributed among the 10 lots.

Prorate. To divide or distribute proportionally.

Proration. A method of distributing discovered excess of deficiency between parties having equal rights or proportionate rights to the excess or deficiency. A method of calibrating the tape of a recent surveyor against that of the original surveyor.

Q

Quarter line. In public land surveys made on a township, range, and section basis, a quarter line is one of two lines joining opposite quarter section corners, and by the two lines the original survey of a section of land is divided into four parts.

R

Range (USPLS). Any series of contiguous townships situated north and south of each other; also sections similarly situated within a township. Ranges of townships are numbered consecutively east and west from a principal meridian; thus "range 3 east" indicates the third range or row of townships to the east from a principal meridian. The word "range" is used in conjunction with the appropriate township to indicate the coordinates of a particular township with reference to the initial point; thus "township 14 north, range 3 east" indicates the particular township which is the 14th township north of the base line and the third township east of the principal meridian.

Reciprocal observations. Observations taken backward and forward such as vertical angles at both terminals of a line for trigonometric leveling.

Reciprocal zenith angles. Zenith angles observations taken with the instrument occupying both ends of a line for trigonometric leveling purposes in order to correct for the effects of refraction, parallax and earth curvature.

Reconnaissance. A general examination or survey of a region with reference to its main features, usually as a preliminary to a more detailed survey.

Recording a deed. The recording of deeds to give constructive notice of conveyance to purchasers and creditors. A deed may be valid between the grantor and grantee but will fail to give constructive notice to others if not so recorded.

Recovery of station. To visit a survey station, identify its mark as authentic and in its original location, and verify or revise its description. The term is usually modified to indicate the type or nature of the recovery, such as recovered bench mark, or a recovered triangulation station.

Reduction to sea level. A reduction applied to a measured horizontal length on the earth's surface to reduce it to the surface of the sea-level datum of the reference spheroid.

Reference mark. A permanent supplementary mark close to a survey station to which it is related by an accurately measured distance and direction, and/or a difference in elevation.

Referencing. The process of measuring the horizontal (or slope) distances and directions (azimuths or bearing) from a survey station to nearby landmarks, reference marks, and other objects that can be used in the recovery of the station.

Reflecting prism. A prism in which deviation of a light beam is produced by reflection within the prism. Almost all prisms used in photogrammetric instruments are of this type.

Refraction. The bending of light rays in passing from one transparent medium into another that has a different index of refraction. The angle of refraction is the angle that the refracted ray makes with the normal to the surface separating the two media.

Refraction, horizontal. The lateral effect of terrestrial refraction that affects the observed values of horizontal directions.

Refraction, index of. The sine of the angle of incidence divided by the sine of the angle of refraction equals a constant when one of the media is air. The index of refraction can also be explained as the ratio of the velocity of light in one medium to that in another. The indices of glass range from 1.46 to 1.80.

Registration.

- The matching of details of a map overlay with the details of the base map in their respectively correct horizontal and/or coordinate position.
- The position correlation of cultural and topographic details printed using different color so as to comprise an accurate topographic or planimetric map.

Relief. Variations in the elevation of the ground surface, also features of height above a plain or reference datum. On a topographic map, relief is depicted by hachures or shading, or more accurately by contours or by spot elevations or both.

Repetition of angles. The accumulation of a series of measures of the same angle on the horizontal circle of a repeating theodolite or surveyor's transit. In making these readings the final reading of one measure is used as the initial setting of the next measure of the angle. The observed value of the angle is obtained by dividing the total arc passed over by the number of observations.

Resection.

- The graphical or analytical determination of a position, as the intersection of at least three lines of known direction to corresponding points of known position.
- (Surveying) The determination of the horizontal position of a survey station by observed directions from the station to points of known positions. Also, the line drawn through the plotted location of a station to the occupied station.
- (Photogrammetry) The determination of the position and/or altitude of a camera, or the photograph taken with that camera, with respect to the exterior coordinate system.

Resection, locating a point by. Locating a point by drawing an indefinite line of known direction from one known point, occupying a station on the line, and determining the direction of a resection line through a second known point. This resection line will cut the indefinite line at the location of the point desired.

Restoration. The recovery of one or more lines or corner positions, or both, of a prior approved survey; or the replacement of one or more lost corners or obliterated monuments by approved methods, including the substantial renewal of one or more monuments, as required for the purpose of a survey.

Resurvey. A retracing on the ground of the lines of an earlier survey, in which all points of the earlier survey that are recovered are held fixed and used as a control. If too few points of the earlier survey are recovered to satisfy the control requirements of the resurvey, a new survey may be made. A resurvey is related directly to an original survey although several resurveys may interpose between them. See also "Resurvey, dependent" and "Resurvey, independent."

Resurvey, dependent. A resurvey for accomplishing a restoration based on the original conditions according to the records. The dependent resurvey is made, first by identifying existing corners and other recognized and acceptable points of control of the original survey, and second, by restoring the missing corners by proportionate measurement in harmony with the original survey. This type of resurvey is used where there is fair agreement between the conditions on the ground and the records of the original survey. Titles, areas, and descriptions should remain unchanged. Contrasted with independent resurvey.

Resurvey, independent. A resurvey that is not dependent on the records of the original survey but is intended to supersede them in establishing new land boundaries and subdivisions. It is made in areas generally having both private and public lands represented in the tract to be resurveyed and

where the ground evidence of the original survey has become entirely lost or the descriptions of the earlier survey are irreconcilable. An independent resurvey is accomplished in three steps: the out-boundaries of lands subject to resurvey are first reestablished, following the method of dependent resurvey; the private lands are segregated, with due consideration for the bona fide rights of the claimants; and new boundaries and descriptions are established for the remaining public lands. Contrasted with dependent resurvey.

Retracement. A term applied to a survey that is made for the purpose of verifying the direction and length of lines, and identifying the monuments and other marks of an established prior survey.

S

Scale factor. A multiplier for reducing a distance obtained from a map by computation or scaling to the actual distance on the datum of the map. Also, in the state coordinate systems, scale factors are applied to geodetic lengths to obtain grid lengths, or to grid lengths or obtain geodetic lengths. Both are lengths on a sea-level datum, but the grid lengths are affected by the distortion of the map projection.

Scribing. Scribing has been defined as the act of marking material with a pointed instrument. As practiced in the graphic-arts field, scribing is akin to engraving. It is an efficient delineation technique that, for the sake of simple explanation, may be said to be the converse of conventional drafting in the projection of line drawings. In drafting, pencil or ink markings are applied to the base sheet; in scribing, material is removed where markings are desired.

Semi-diameter. In making observation of the sun or the moon, the angle should be measured to one edge (or limb) of the body, and the observed angle should be reduced to the center by adding or subtracting the apparent semi-diameter. This quantity may be found in the Nautical Almanac. For the sun, it is approximately 16 minutes of arc but varies about 15 seconds of arc either way.

Set of angles. A set of angles consists of two pointings of an instrument. For horizontal angles, a set consists of direct and reverse pointing of the instrument. For zenith angles, a set consists of a left (vertical circle left) and a right (vertical circle right) pointing of the instrument. A meaned set of angles removes systematic instrument adjustment and leveling errors from an observation. Correct operation of instruments requires a minimum of one set of angles for traverse or layout work.

Side shot. A reading or measurement from a survey station to locate a point that is not intended to be used as a base for the extension of the survey. A side shot is usually made for the purpose of determining the position of some object that is to be shown on the map.

Single proportionate measurement. A method of proportioning measurement in the restoration of a lost corner whose position is determined with reference to alignment in one direction. Examples of such corners are quarter-section corners on the line between two section corners, all corners on standard parallels, and all intermediate positions on any township boundary line. The ordinary field problem consists of distributing the excess of deficiency between two existent corners in such a way that the amount given to each interval bears the same proportion to the whole difference as the record length of the interval bears to the whole distance. After having applied the proportionate difference to the record length of each interval, the sum of the several parts will equal the new measurement of the whole distance.

Spheroid. A figure almost a sphere but not spherical.

Stadia. A technique of distance measurement wherein the observer reads the intercept subtended on a graduated rod between two hairs or marks on the reticle of the telescope, the distance of the rod

being proportional to the rod intercept. A rod specially designed for this use is called a stadia rod; the marks on the reticle are called stadia wires; such a survey is called a stadia survey, etc.

Station. A term meaning a point every 100 feet on centerline; in traversing, the name of a traverse point. Basically, the name of a point.

Stereocomparator (photogrammetry). A stereoscopic instrument for measuring parallax which usually includes a device for measuring photograph coordinates of image points.

Stereocompilation.

- The procedure of producing a map from aerial photographs by means of stereoplotting instruments.
- The map data produced with stereoplotting instruments.

Stereoscope. An optical instrument used for viewing two properly related photographs or diagrams simultaneously to obtain the mental impression of a three-dimensional model.

Stereoscopic fusion. The mental process that combines two perspective views to give an impression of a three-dimensional model.

Stereoscopic principle (photographic mapping). The formation of a single, three-dimensional image by binocular vision of two photographic images of the same terrain taken from different exposure stations. With proper equipment all measurements needed in map construction can be made from this visual model.

Strike (geology and mining). The direction of a line formed by the intersection of a bedding plane, vein, fault, slaty cleavage, schistosity, or similar geological structure, with a horizontal plane. It is at right angles to the dip.

Strip adjustment. Similar to a block adjustment, but limited to a single strip of photographs.

Subchord. Any chord of a circular curve whose length is less than that of the chord adopted for laying out the curve. In a railroad curve, for example, a subchord is a chord less than 100 feet in length. Also, any chord of a circular curve that is less than the long chord between the extremities of the curve.

Subdivision (real estate). A tract of land surveyed and divided into lots for purposes of sale. In some localities it is distinguished from a development upon which improvements are made before sale; in other localities the terms are synonymous.

Subdivision (USPLS). The subdivision of a township, such as a section, half-section, quarter-section, quarter-quarter or sixteenth-section, or lotting, including the lot, section, township, and range numbers, and the description of the principal meridian to which referred, all according to the approved township plat.

Subtangent. The length of a line tangent to the arc of a circle from an extremity of said arc to its intersection with a similar line tangent to the other extremity of said arc; also termed semi-tangent.

Subtense bar. A horizontally held bar of precisely determined length, used to measure distances by observing the angle it subtends at the distance to be measured.

Surveying.

- The science and art of making all essential measurements in space to determine the relative position of points and/or physical and cultural details above, on, or beneath the surface of the

earth and to depict them in usable form, or to establish the position of points and/or details. Also, the actual making of a survey and the recording and/or delineation of dimensions and details for subsequent use.

- The acquiring and/or accumulation of qualitative information and quantitative data by observing, counting, classifying, and recording according to need. Examples are traffic surveying to determine the type, number, speed, relative positions, and origin and destination of vehicles; and soil surveying to classify soil by type and measure and delineate their boundaries.

Surveying, geodetic. That branch of the art of surveying in which account is taken of the figure and size of the earth. In geodetic surveying, prescribed precision and accuracy of results are obtained through the use of special instruments and field methods and equations based on the geometry of a mathematical figure approximating the earth in form and size.

Surveying, land. Land surveying is the art and science of:

- re-establishing cadastral surveys and land boundaries based on documents of record and historical evidence;
- planning, designing and establishing property boundaries; and
- certifying surveys as required by statute or local ordinance such as subdivision plats, registered land surveys, judicial surveys, and space delineation.

Land surveying can include associated services such as mapping and related data accumulation; construction layout surveys; precision measurements of length, angle, elevation, area and volume; horizontal and vertical control systems; and the analysis and utilization of survey data.

Surveying, plane. A branch of the art of surveying in which the surface of the earth is considered a plane surface. For small areas, precise results may be obtained with plane-surveying methods, but the accuracy and precision of such results will decrease as the area surveyed increases in size.

Surveying, route. For locating, designing, and constructing a railroad, highway, canal, pipeline, transmission line, or other linear facility. Route surveying comprises all reconnaissance surveys, the preliminary survey, the location survey, and surveys made during construction.

T

Tangent. Also called semi-tangent.

- A straight line that touches a given curve at one and only one point and does not intersect it.
- In route alignment, that part of alignment from one P.I. to the next P.I.; the distance from the P.T. of one curve to the P.C. of the next curve; or the distances from the P.C. to P.I. and P.I. to P.T. of a curve.

Taping. The operation of measuring distances on the ground with a tape or chain. Formerly the words "chaining" and "taping" were used synonymously, but the word "taping" is now preferred for all surveys except those of the public-land system. For the latter, because of historical and legal reasons, the term "chaining" is preferred. See also "Chaining."

Taping (breaking tape). A method of taping on slopes whereby all measurements are made with a part of the tape held horizontally.

Taping, standard tension. The tension or pull at which a tape was standardized.

Target.

- Any object or point toward which something is directed.
- An object that reflects a sufficient amount of a radiated signal to produce an echo signal on detection equipment.

Target, photographic. A pre-marked image point used to control the photography for mapping purposes or to extend control by photogrammetric methods. A target is centered over a point that would otherwise not be visible on a photo. A target generally is black and white and may be made of various materials (for example: paint, plastic, cloth or lumber). Also called signals or panels. The preferred term is photographic target.

Thence. In surveying, and in descriptions of land by courses and distances, this word, preceding each course given, imports that the following course is continuous with the one before it.

Theodolite. A precision surveying instrument consisting of an alidade with a telescope. It is mounted on an accurately graduated circle and is equipped with necessary levels and reading devices. Sometimes, the alidade carries a graduated vertical circle. There are two general classes of theodolites: direction theodolites and repeating theodolites.

Theodolite, directional instrument. A theodolite in which the graduated horizontal circle remains fixed during a series of observations. The telescope is pointed on a number of signals or objects in succession, and the direction of each is read on the circle, usually by the use of micrometer microscopes. In measuring horizontal angles with a direction instrument, angles are not repeated (accumulated) on the circle, but precision and accuracy are obtained by having the circle of high quality, by using precision methods of reading the circle, and by shifting the circle between sets so that each direction is measured on a number of different parts of the circle. Direction instruments are used almost exclusively in first-order and second-order triangulation.

Theodolite, repeating instrument. A theodolite so designed that successive measures of an angle may be accumulated on the graduated circle, and a final reading of the circle which represents the sum of the repetitions may be made. The observed value of the angle is obtained by dividing the total arc passed through in making the series of observations by the number of times the angle has been observed. The total arc passed through may include several complete circuits of the circle, which must be added to the circle reading before making the division. The repeating theodolite is also termed a repeating instrument. Theoretically, it is an instrument of great precision, but in its mechanical operation it does not give results as satisfactory as the directional instrument.

Tilt (photogrammetry). The angle at the perspective center between the photograph perpendicular and the plumbline (or other exterior reference direction); also, the dihedral angle between the plane of the photograph and the horizontal plane. The direction of tilt is expressed by swing (when referred to the axes of the photograph) or azimuth (when referred to the exterior coordinate system). In aerial photography, tilt may be separated into its component angles, referred to the fiducial axis, with the x axis being the one more nearly in the direction of flight. In aerial-camera orientation, a positive x tilt results from the left wing of the aircraft being lowered, displacing the nadir point in the positive y direction. Similarly a positive y tilt results from the nose of the aircraft being lowered, displacing the nadir point in the positive x direction.

Total stations. Total stations are classified as automatic or manual. Field procedures are different for the two classes.

Traverse. A method of surveying in which lengths and directions of lines between points on the earth are obtained by or from field measurements, and used in determining positions of the

points. A survey traverse may determine the relative positions of the points that it connects in series, and if tied to control stations on an adopted datum, the positions may be referred to that datum. Survey traverses are classified and identified in a variety of ways: according to methods used, as astronomical traverse; according to quality of results, as first-order traverse; according to purpose served, as geographical-exploration traverse; and according to form as closed traverse, etc.

Traverse, closed. A survey traverse that starts and ends upon the same station, or upon stations whose relative positions have been determined by other surveys of equal or higher order of accuracy.

Traverse, open. A survey traverses that begins from a station of known or adopted position, but does not end upon such a station. Also termed an open-end traverse.

Triangulation. A method of surveying in which the stations are points on the ground at the vertices of a chain or network of triangles. The angles of the triangles are measured instrumentally and the sides are derived by computation from selected sides or bases, the lengths of which are obtained by direct measurement on the ground or by computation from other triangles. A triangulation system of limited width (generally that of one triangle), designed to progress in a single general direction, is designated arc triangulation, and the chain of triangles (or polygons composed of abutting or overlapping triangles) is called a triangulation arc. A network of triangulation designed to cover an area with abutting or overlapping triangles is designated area triangulation, and the resulting configuration is called a triangulation net.

Triangulation (photogrammetry). Also termed stereo-triangulation. The use of a stereoscopic plotting instrument to establish both horizontal and vertical control data by the successive orientation of the stereoscopic pairs of photographs in a continuous strip. Orientation of the initial model is by reference to ground control established by survey methods. The stereo-triangulation may be of the cantilever type with ground control confined to the initial model or of the bridging type with control available in both initial and terminal models. Bridging to determine horizontal positions is the principal application of stereo-triangulation. Determination of accurate altimetric data by stereo-triangulation requires accessory equipment such as the horizon camera with statoscope. Furthermore, refined analysis must be applied to eliminate error caused by the functional characteristics of the aerial camera-stereoscopic plotter combination.

Tribrach. The three-arm base of a surveying instrument that carries the foot-screws used in leveling the instrument.

Trilateration. A method of surveying wherein the lengths of the triangle sides are measured, usually by electronic methods, and the angles are computed from the measured lengths. Compare with triangulation.

True value. That value of quantity that is completely free from blunders and errors. Since the errors to which physical measurements are subject cannot be known exactly, it follows that the true value of a quantity cannot be known with exactness. In survey work, the most probable value is used as best representing the true value of the quantity.

Turning point (T.P.). In differential leveling, a point, the height of which is determined before the leveling instrument is moved, used to determine the height of the instrument after resetting.

U

Underground mark. A surveying mark set and plumbed below the center of a surface mark and separated therefrom so as to preserve the station in case of accident to the surface mark.

V

Variation of the compass. Difference between true north as determined by the earth's axis of rotation and magnetic north as determined by the earth's magnetism. The variation is designated as east or positive when the magnetic needle is deflected to the east of true north, and as west or negative, when the deflection is to the west of true north. Also called magnetic declination.

Vernier. An auxiliary scale sliding against and used in reading a primary scale. The total length of a given number of divisions on a vernier is equal to the total length of one more or one less than the same number of divisions on the primary scale.

The vernier makes it possible to read a principal scale (such as a divided circle) much closer than one division of that scale. If a division on the primary scale is longer than a single division on the vernier, it is a direct vernier; if a division on the vernier is the longer, it is a retrograde vernier, so called because its numbers run in the opposite direction from those on the primary scale. The direct vernier is the usual type and is used in reading the circles on an engineer's transit and on a repeating theodolite. Two verniers extending and numbered in opposite directions from the same index form a double vernier, used in reading a circle having graduations numbered in both directions. A single vernier so constructed and numbered that it may be read in either direction is termed a folding vernier.

Vertical angle. An angle between two intersecting lines in a vertical line.

Vertical control. Established bench marks.

Vertical control point. A targeted or photo I.D. point that has only vertical or elevation control established. In order to properly control photographs for highway mapping purposes, it is necessary to have more vertical control points than horizontal control. When leveling to vertical control points, three elevations at the point need to be recorded, even if they are the same. First, the elevation of the monument set at the point is required. This is the point through which the level circuit will be closed. Second is the elevation of the ground at the center of the target (the mean elevation of a one-foot diameter circle around the point). The third is the elevation of the center of the target. This is important when the point and the ground are in a depression which the target bridges.

Viewfinder (aerial photogrammetry). A device similar to a camera but with the ground glass in the focal plane of the lens. The viewfinder is mounted vertically in the floor of an airplane for the purpose of viewing the landscape and determining when photographs should be taken. It is graduated to determine the spacing between photographs necessary to obtain the desired overlap. Because the viewfinder is aligned with the true direction of flight, the angle of crab between the longitudinal axis of the plane and the direction of flight can be obtained.

W

Watershed. The area contained within a drainage divide above a specified point on a stream. In water-supply engineering it is termed a watershed, and in river-control engineering it is termed a drainage area, drainage basin, or catchment area.

Weight (surveying). The relative reliability (or worth) of a quantity as compared with other values of the same quantity. If one value of a quantity has a weight of 2, and another value of the same quantity has a weight of 1, the first value is worth twice the second value, and a mean value would be obtained by taking a weighted mean twice the first value plus once the second value, the sum being divided by 3.

Wiggling in. A survey procedure used when it is necessary to establish a point, exactly on line between two control points, neither of which can be occupied. It is essentially a trial-and-error technique where repeated fore and back readings are taken and the instrument is shifted after each pair of readings until exactly in line with the stations. Also called ranging in.

Wing point. A vertical control point, either targeted or identified as a picture point, usually placed in the corners of the neat model.

Witness mark. A material mark placed at a known distance and direction from a property corner, instrument, or other survey station, to aid in its recovery and identification. In surveying, a witness mark is established as an aid in the recovery and identification of a survey station, or other point to which it is a witness. A mark which is established with such precision and accuracy that it may be used to restore or take the place of the original station is more properly called a reference mark in control surveys, and a witness corner in land surveys. Also called witness post or witness stake.

Witness point (USPLS). A monumented station on a line of the survey.

Witness post. Delineator post driven three feet southwest of basic ground control survey stations.

Witness sign. A metal fence post or composite fiber post with a "Do Not Disturb Survey Monument" sign attached. The witness sign is set close to a survey control point to aid in its protection and recovery.

X

X, Y, and Z coordinates. Three separate coordinate values that are referenced to a known or adopted datum. The "X" value is an east-west or longitudinal coordinate. The "Y" value is a north-south or latitudinal coordinate value. The "Z" value is an elevation value. When coordinates are computed or listed, it is common practice to list the "Y" (northerly) value first, next the "X" (easterly) value, and then the "Z" (elevation) value.

Z

Zenith. Where the point produced by a plumb line projected up from the observer meets the Celestial Sphere.

Zenith angle. An angle measured from the zenith (straight up) to a point. In modern survey instruments, the zenith angle replaces the vertical angle and is used to reduce slope measurements to horizontal and vertical differences. The use of zenith angles correctly signs the value of the vertical difference for computer computation.

Abbreviations

Abrupt	AB.
Adjusted	ADJ.
Ahead	AHD.
Ahead Stationing	AH.
And	&
Aluminum Cap	A.C.
At	@
Avenue	AVE.
Average	AVG.

Azimuth	AZ.
Back	BK.
Back Stationing	BK.
Backsight	B.S.
Barbed Wire Fence	B.W.FE.
Base of Rail	B.R.
Bearing	BRG.
Begin	BEG.
Bench Mark	B.M.
Bottom	BOT.
Boulevard	BLVD.
Boundary	BNDRY.
Brass Cap	B.C.
Bridge	BR.
Bridge End	B.E.
Building	BLDG.
Bureau of Land Management	B.L.M.
Calculated	CALC.
Cast Iron Pipe	C.I.P.
Catch Basin	C.B.
Catch Point	C.P.
Cement Treated Base	C.T.B.
Centerline	C/L
Centimeter	CM.
Chain	CH.
Chain Link Fence (w/ height)	CL-4F,5F,6F
Chord	CHD.
Chiseled Cross	CHIS."x"
Circle	CIR.
Clean Out	C.O.
Closing Corner	C.C.
Cloudy	CLDY.
Concrete	CONC.
Concrete Block Wall	C.B.W.
Concrete Nail	C.N.
Condition	CDTN.
Conduit (specify type)	COND.(TEL.)
Construction	CONST.
Control of Access	C/A
Corner	COR.
Corrected	CORR.
Corrugated Metal Pipe	C.M.P.
Corrugated Steel Pipe	C.S.P.
County	CO.
Court	CT.

Creek	CR.
Crossing	XING.
Cross Section	XSEC.
Culvert	CULV.
Curb	CB.
Curb and Gutter	C.&G.
Curve to Spiral	C.S.
Cut	C.
Daylight	DY.
Deep	DP.
Deflection	DEFL.
Degree of Curvature	D.
Department of Transportation	D.O.T.
Description	DESC.
Destroyed	DEST.
Detour	DET.
Diameter	DIA./D
Difference in Elevation	DE
Distance	DIST.
District	DIST.
Ditch	DT.
Double	DBL.
Down	DN.
Down Drain	D.D.
Drain	DR.
Drill Hole	D.H.
Drive	DR.
Driveway	DRWY.
Drop Inlet	D.I.
East	E.
East Bound	E.B.
Easterly	ELY.
Edge of Gutter	E.G.
Edge of Oil	E.O.
Edge of Pavement	E.P.
Edge of Shoulder	E.S.
Edge of Traveled Way	E.T.W.
Electronic Distance Measurement or Measurer	E.D.M.
Elevation	EL. or ELEV.
End Wall	EW.
Equation	EQ.
Existing	EX.
Expressway	EXWY.
External	EXT.
Fahrenheit	F

Fence	FE.
Fence Post	F.P.
Feet	FT.
Field Book	F.B.
Fill	F.
Finish Grade	F.G.
Finish Grade Stake	F.G.S.
Fire Hydrant	F.H.
Flood Control	F.C.
Flow Line	F.L.
Flush	FL.
Foot	FT.
Footing	FTG.
Foresight	F.S.
Found	FD.
Foundation	FDN.
Freeway	FWY.
Frontage Road	FR. RD.
Galvanized	GALV.
Galvanized Steel Pipe	G.S.P.
Gas Line	G.L.
Gas Valve	G.V.
Geodetic	GEOD.
Global Positioning System	G.P.S.
General Land Office	G.L.O.
Grade Separation	GR.SEP.
Grid	GRD.
Ground	GRND.
Guard Rail	G.R.
Gutter	GTR.
Headwall	HDWL.
Height	HT.
Height of Instrument	HI
Highway	HWY.
High Water	H.W.
Hinge Point	H.P.
Horizontal	HORIZ.
Hub & Tack	H.&T.
Inch	IN.
Inside Diameter	I.D.
Instrument	INSTR.
Interchange	INTCH.
Intersection	INT.
Invert	INV.
Iron Pin	I.P.

Irrigation Pipe	IRR.P.
Joint Use Pole	J.P.
Junction	JCT.
Kilometer	KM.
Land Surveyor	L.S.
Lane	LN.
Left	LT.
Length of Circular Curve	L_c.
Length of Spiral Curve	L_s.
Length of Vertical Curve	L.
Long Chord	L.C.
Manhole	M.H.
Marker	MKR.
Maximum	MAX.
Measured	MEAS.
Median	MED.
Meter	M.
Mid Ordinate	M.O.
Mid-Point of Curve	M.P.C.
Mile	MI.
Millimeter	MM.
Minimum or Minute	MIN.
Nail	NL.
National Geodetic Survey	N.G.S.
National Oceanic and Atmospheric Administration	N.O.A.A.
Natural Gas Line	N.G.
Normal Water Elevation	N.W.EL.
North	N.
North Bound	N.B.
Northerly	NLY.
Number	# or NO.
Offset	O/S or O.
Old Ground	O.G.
On Centers	O.C.
Original Ground	O.G.
Outside Diameter	O.D.
Overhang	OH.
Overhead Crossing	O.C.
Overhead	OH.
Page	P. or PG.
Pages	PP.
Parker-Kalon Nail	PK.N.
Parts per Million	P.P.M.
Party Chief	P.CHF.
Pavement	PVMT.

Penny (i.e.: 60d nail)	d
Perforated Metal Pipe	P.M.P.
Pipe	P.
Place	PL.
Plant Mixed Surface	P.M.S.
Plastic	PLAS.
Plate	PL.
Point	PT.
Point of Curvature	P.C.
Point of Compound Curvature	P.C.C.
Point of Intersection	P.I.
Point on Curve	P.O.C.
Point on Line	P.O.L.
Point on Semi-Tangent	P.O.S.T.
Point on Tangent	P.O.T.
Point on Vertical Curve	P.O.V.C.
Power Pole	PWR.P.
Present Traveled Way	P.T.W.
Principal Meridian	P.M.
Private	PVT.
Professional Engineer	P.E.
Profile Grade	P.G.
Project	PROJ.
Projected	PROJ.
Project Control System	P.C.S.
Property Line	P.L.
Pull Box	P.B.
Punch Mark	P.M.
Radial	RDL.
Radius	R.
Radius Point	RAD.PT.
Railroad or Railway	R.R.
Range	R.
Reference Point	R.P.
Record	REC.
Reference	REF.
Reference Monument	R.M.
Reference Point	R.P.
Reinforced Concrete Box	R.C.B.
Reinforced Concrete Pipe	R.C.P.
Retaining Wall	RET.W.
Right	RT.
Right of Way	R/W
River	RIV.
Road	RD.

Roadway	RDWY.
Rounding	RN.
Route	RT.
Satellite (For traverse use)	SA.
Sea Level Datum	S.L.D.
Second	SEC.
Section	S.
Sewer Line (Sanitary)	S.S.
Sheet	SHT.
Shoulder	SH.
Sidewalk	SW.
Slope Stake	SLP. STK.
South	S.
South Bound	S.B.
Southerly	SLY.
Spike	SPK.
Spiral to Curve	S.C.
Spiral to Tangent	S.T.
Stake	STK.
Staked	STKD.
Stamped	STPD.
Standard	STD.
Stand Pipe	S.P.
State Plane	S.P.
Station	STA.
Steel	STL.
Steel Pipe, High Pressure	S.P.H.P.
Steel Sectional Plate Pipe	S.S.P.P.
Storm Drain	S.DR.
Storm Sewer	S.
Street	ST.
Structure	STR.
Subdivision	SUBD.
Subgrade	S.G
Surfacing	SURF.
Survey	SURV.
Tack	TK.
Tangent	TAN.
Tangent Length of Curve	T.
Tangent to Spiral	T.S.
Telephone Cable	TEL. C.
Telephone Pole	TEL. P.
Temperature	TEMP.
Temporary Bench Mark	T.B.M.
Top Back of Curb	T.B.C.

Topographic	TOPOG.
Township	T.
Tract	TR.
Transmission Tower	T.T.
Traverse	TRAV.
Triangulation	TRIA.
Turning Point	T.P.
U.S. Bureau of Land Management	B.L.M.
U.S. Coast & Geodetic Survey	U.S.C.&G.S.
U.S. Corps of Engineers	U.S.C.E.
U.S. Forest Service	U.S.F.S.
U.S. Geological Survey	U.S.G.S.
U.S. Public Land Survey	U.S.P.L.S.
Vent Pipe	V.P.
Vertical	VT.
Vertical Angle Bench Mark	V.A.B.M.
Vertical Control Monument	V.C.M.
Vertical Curve	V.C.
Vertical Curve Offset Correction	V.C.CORR.
Vitrified	VIT.
Vitrified Clay Pipe	V.C.P.
Warped or Variable Slope	W.S.
Water Line	W.L.
Water Service	W.S.
Water Table	W.T.
Water Valve	W.V.
Welded Steel Pipe	W.S.P.
West	W.
West Bound	W.B.
Westerly	WLY.
Wing Point	W.P.
Wing Wall	W.W.
With	W/
Witness Corner	W.C.
Woven Wire	W.W.

Surveyor's Measures And Conversions

Constants

- **Pi, π** — The number that denotes the ratio of the circumference of a circle to its diameter.

  Approximate method: $\frac{22}{7}$ or 3.14

  More exact: 3.1415926536

- **Radian** — The central angle of a circular arc that is equal in length to the radius of the arc.

  $\frac{180°}{\pi}$ = 57.29577951° = one radian

- **Earth's Mean Radius:**

  Feet — 20,906,000
  Miles — 3,959.5
  Kilometers — 6,372

- **Temperature Conversion** (Fahrenheit and Celsius)

	F	C
Freezing	32°	0°
Boiling	212°	100°
Ratios	1°:0.55° C	1°:1.8° F
C to F	$\frac{3}{5}$ C + 32°	
F to C	$\frac{5}{9}$(F - 32°)	

Abbreviations

Linear — U.S.

Chain	= ch.	Link	= lk.
Fathom	= fm.	Mile	= mi.
Foot	= ft. or '	Pole	= pl
Furlong	= fur.	Rod	= rd.
Inch	= in. or "	Yard	= yd.

Linear — Metric

Centimeter	= cm	Metro	= m
Decameter	= dkm	Micron	= μ
Decimeter	= dm	Millimeter	= mm
Hectometer	= hm	Myriameter	= mym
Kilometer	= km		

Square Measure — U.S. and Metric

Preface the linear abbreviation with "sq.," as "2 sq. mi.," or add the exponent, "^{2}," as "2 mi.^{2}." Do not confuse these two terms which indicate an area of 2 square miles with the term "2 miles squared" which indicates an area of 4 square miles.

Land Area Terms — U.S. and Metric

Acre	= A	Centare	= ca
Section	= S	Are	= a
Township	= T	Hectare	= ha
Range	= R		

Measures

Linear — U.S.

Links —

1 lk. = 7.92 in.
25 lk. = 16 1/2 ft. = 1 rd.
100 lk. = 1 ch.

Chains —

1 ch. = 66 ft. = 100 lk. = 4 rd.
10 ch. = 1 fur. = 1/8 mi.
80 ch. = 1 mi.

Rods or Poles —

1 rd. = 16 1/2 ft. = 25 lk.
4 rd. = 1 ch.
40 rd. = 1 fur.
320 rd. = 1 mi.
1 rd. = 1 pl.

Inches, feet and yards —

12 in. = 1 ft.
3 ft. = 1 yd.
5 1/2 yds. = 1 rd.
5,280 ft. = 1 statute mi.
6076.1033 ft. = 1 nautical mi.
6 ft. = 1 fathom

Linear — Metric

Meters —

0.001 m = 1 mm
0.01 m = 1 cm
0.1 m = 1 dm
10 m = 1 dkm
100 m = 1 hm
1,000 m = 1 km
10,000 m = 1 mym
1,852 m = 1 nautical mi.

Millimeters —

1 mm = 1,000 μ
10 mm = 1 cm
100 mm = 1 dm
1,000 mm = 1 m

Area — U.S.

Acre —

1 A = 43,560 sq. ft.
1 A = 160 sq. rds.
1 A = 10 sq. ch.
640 A = 1 sq. mi.
640 A = 1 S

Square Mile —

1 sq. mi. = 6,400 sq. ch.
1 sq. mi. = 640 A
1 sq. mi. = 1 S
36 sq. mi. = 1 T

Area — Metric

Square Meters —

1 sq. m = 1 ca
100 sq. m = 1 sq. dkm = 1 a
10,000 sq. m = 1 sq. hm = 1 ha
1,000,000 sq. m = 1 sq. km = 100 ha
100,000,000 sq. m = 1 sq. mym

Land Area Terms —

1 ca = 1 sq. m
1 a = 100 sq. m
1 ha = 100 a
1 sq. km = 100 ha
1 sq. mym = 10,000 ha

Conversions

U.S. To Metric — Linear

0.001 ft. = 0.000304800610 m
0.01 ft. = 0.00304800610 m
1 in. = 0.0254000508 m
0.1 ft. = 0.0304800610 m
1 lk. = 0.201168402 m
1 ft. = 0.304800610 m
1 yd. = 0.914401829 m
1 fm. = 1.82880366 m
1 rd. = 5.02921006 m
1 pl. = 5.02921006 m
1 ch. = 20.1168402 m
1 fur. = 201.168402 m
1 mi. = 1609.34722 m = 1.60934755 km

Metric to U.S. — Linear

1 mm = 0.03937 in. (exact) = 0.00328083333 ft.
1 cm = 0.3937 in. (exact) = 0.0328083333 ft.
1 dm = 3.937 in. (exact) = 0.328083333 ft.
1 m = 3.28083333 ft.
1 dkm = 32.8083333 ft.
1 hm = 328.083333 ft.
1 km = 0.621369949 mi.
1 mym = 6.21369949 mi.

Linear conversions are based on 1 meter = 39.37 inches, exactly. The above conversions are equivalent to 1 foot = 0.30480061 meter (a survey foot). The international foot is rounded to 0.30480000 or 0.3048 meter.

Conversions for the State Plane Coordinate System require the use of the international foot. Use the survey foot for normal conversions.

U.S. to Metric — Area

1 sq. in. = 6.45162581 sq. cm
1 sq. ft. = 929.034116 sq. cm = 0.0929034116 sq. m = 0.0929034116 ca
1 sq. yd. = 0.836130705 ca
1 sq. rd. = 25.2929538 ca
1 sq. ch. = 404.687261 ca = 4.04687261 a
1 A = 40.4687261 a = 0.404687261 a = 4,046.87261 ca
1 sq. mi. = 258.999847 ha = 2.58999847 sq. km

Metric to U.S. — Area

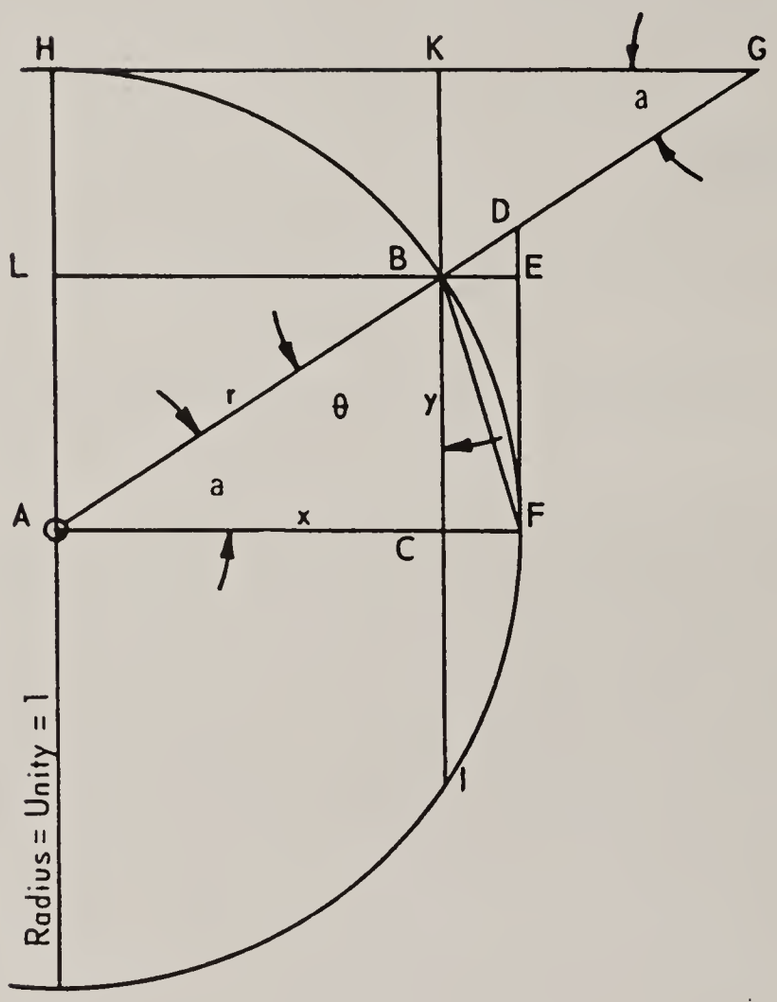
1 sq. cm	= 0.15499969 sq. in. (exact)
1 ca	= 10.7638674 sq. ft.
1 a	= 1,076.38674 sq. ft.
1 ha	= 107.638674 sq. ft. = 2.47104393 A
1 sq. km	= 247.104393 A = 0.3861006 sq. mi.
1 sq. mym	= 6.45162581 sq. cm

Appendix D

Basic Trigonometry

Appendix D provides basic trigonometric formulas for solving of unit circles, right triangles and oblique triangles.

Unit Circles and Formulas



Radius = Unity = 1
AF = AB = AH = 1

A = angle BAC
θ = angle ABC

sine a = BC = 1/csc a
cosine a = AC = 1/sec a
tangent a = DF = 1/cot a
cotangent a = GH = 1/tan a
secant a = AD = 1/cos a
cosecant a = AC = 1/sin a
versine a = BE = CF = 1 - cos a
coversine a = BK = HL = 1 - sin a
exsecant a = BD = sec a - 1
coexsecant a = BG = csc a - 1
haversine a = $\frac{1}{2}$ vers a
chord a = BF
chord 2a = 2BC = 2 sin a

Hypotenuse of a = AB = r; Adjacent side = AC = x; Opposite side = BC = y

$\sin a = y/r = \cos \theta$

$\cos a = x/r = \sin \theta$

$\tan a = y/x = \cot \theta$

$\cot a = x/y = \tan \theta$

$\sec a = r/x = \csc \theta$

$\csc a = r/y = \sec \theta$

$y = \sqrt{(r + x)(r - x)} = \sqrt{r^2 - x^2}$

$x = \sqrt{(r + y)(r - y)} = \sqrt{r^2 - y^2}$

$r = \sqrt{x^2 + y^2}$

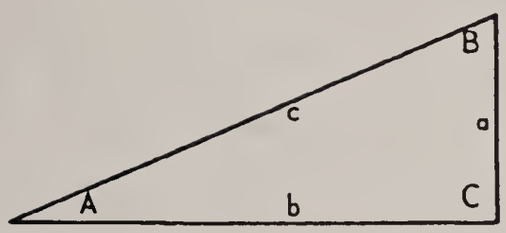
$\text{vers } a = \frac{r - x}{r} = 1 - \frac{x}{r} = \text{covers } \theta$

$\text{exsec } a = \frac{r - x}{x} = \frac{r}{x} - 1 = \text{coexsec } \theta$

$\text{covers } a = \frac{r - y}{r} = 1 - \frac{y}{r} = \text{vers } \theta$

$\text{coexsec } a = \frac{r - y}{y} = \frac{r}{y} - 1 = \text{exsec } \theta$

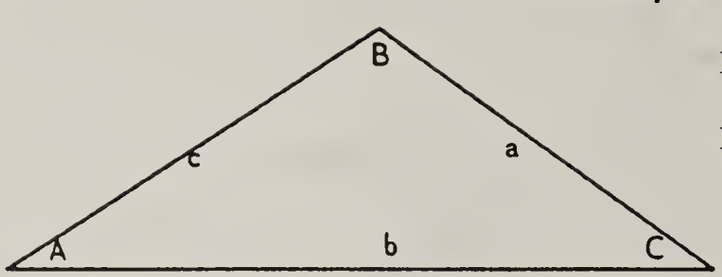
Right Triangles



C = 90 degrees

Given	To Find	Formulas
a, b	c	$\sqrt{a^2 + b^2}$
	A	$\tan A = \frac{a}{b}$ or $\cot A = \frac{b}{a}$
	B	$\tan B = \frac{b}{a}$ or $\cot B = \frac{a}{b}$
	Area	$\frac{a\,b}{2}$
a, c	b	$\sqrt{c^2 - a^2}$
	A	$\sin A = \frac{a}{c}$
	B	$\cos B = \frac{a}{c}$ or 90° - A
A, a	b	$\frac{a}{\tan A}$
	c	$\frac{a}{\sin A}$
	B	90° - A
A, b	a	b (tan A)
	c	$\frac{b}{\cos A}$
	B	90° - A
A, c	c	c sin A
	b	$\frac{c}{\cos A}$
	B	90° - A

Oblique Triangles



Law of Sines: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$

Law of Cosines: $a^2 = b^2 + c^2 - 2bc \cos A$

or $\cos A = \frac{b^2 + c^2 - a^2}{2bc}$

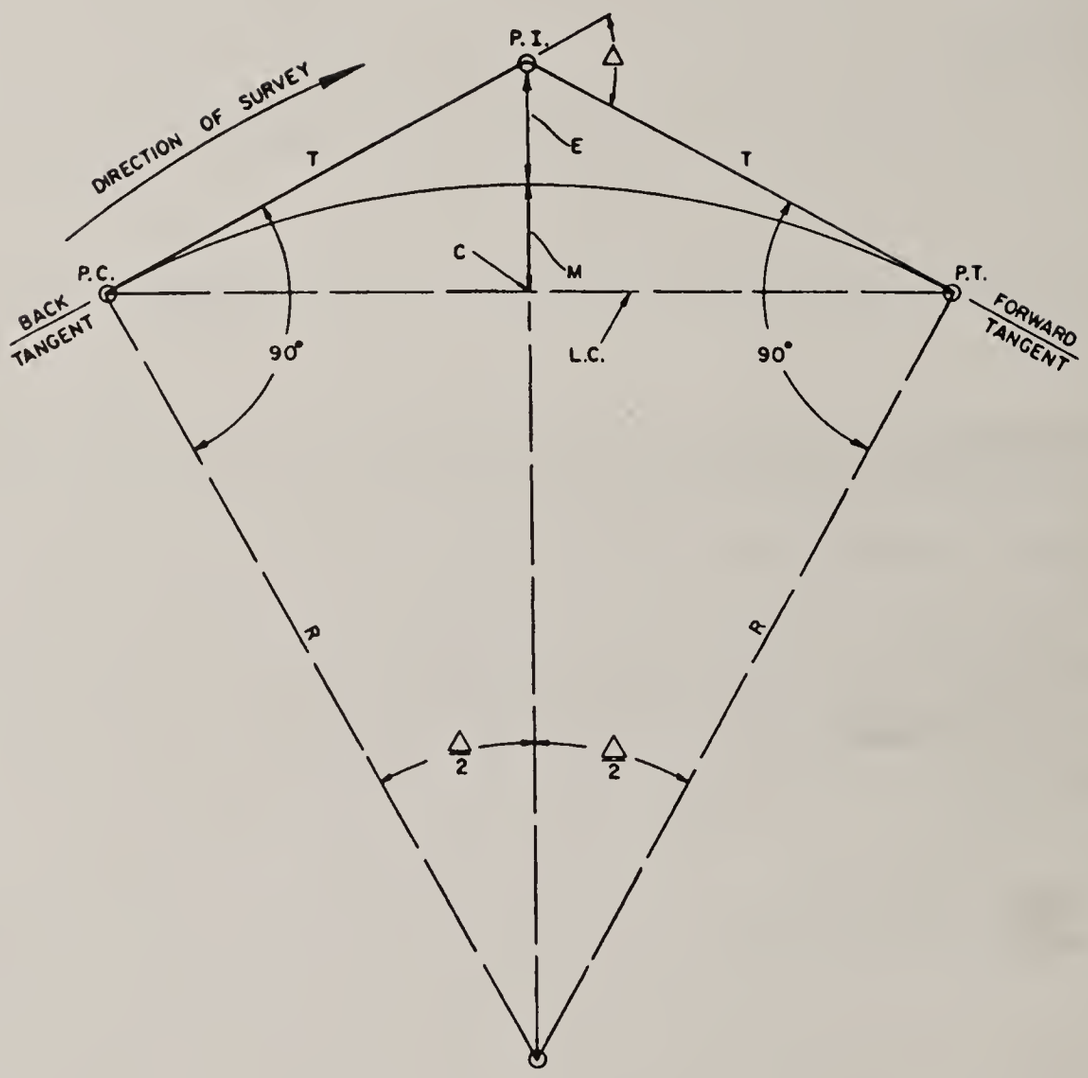
Given	To Find	Formulas
a, b, c	A, B, C	Law of Cosines, or
	Using "s"	$\sin \frac{1}{2} A = \sqrt{(s - b)(s - c)/bc}$; $\cos \frac{1}{2} A = \sqrt{s(s - a)/bc}$
		$\sin A = \frac{2\sqrt{s(s - a)(s - b)(s - c)}}{bc}$
		Note: For angles B & C make appropriate substitutions in these formulas.
		Note: The value "s" = $\frac{1}{2}(a + b + c)$
	Area	$\sqrt{s(s - a)(s - b)(s - c)}$
a, A, B	b	Law of Sines
	C	$180° - (A + B)$
	c	Law of Sines
	Area	$\frac{a^2 \sin B \sin (A + B)}{2 \sin A}$
a, b, A	B	Law of Sines
	C	$180° - (A + B)$
	c	Law of Sines
a, b, C	c	Law of Cosines
	A	$\tan A = \frac{a \sin C}{b - (a \cos C)}$
	B	$180° - (A + C)$
	Area	$\frac{1}{2} ab \sin C$
ABC, a	Area	$\frac{a^2 (\sin B)(\sin C)}{2 \sin A}$

Appendix E
Curves

The formulas for computing the various curves used by the Department are presented in Appendix E.

Curve	Page
Circular Curves	E-2
Spiral Curve Transitions	E-6
Compound Curve Computations	E-8
Three Center Curves	E-10
Short radius Curves	E-12
Parabolic Vertical Curves	E-14
Parabolic Curb Flares	E-15
Parabolic Tapers	E-15
Symmetrical Vertical Curves	E-16
Unsymmetrical Vertical Curves	E-17

Circular Curves



P. I. = Point of Intersection
P. C. = Point of Curvature
P. T. = Point of Tangency
Δ = Deflection angle between the tangents
T = Tangent distance
E = External distance
R = Radius of the circular curve
M = Middle ordinate
L. C. = Long chord (Distance between P. C. and P. T.)
C = Midpoint of the long chord
D = Degree of curvature

General Formulas for Arc Definition

$$T = R \tan \frac{\Delta}{2}$$

$$D = \frac{5729.578}{R}$$

$$L.\ C. = 2\ R \sin \frac{\Delta}{2}$$

$$E = T \tan \frac{\Delta}{4} \text{ or } E = R \operatorname{exsec} \frac{\Delta}{2} \text{ or } E = R \sec \frac{\Delta}{2} - R$$

$$M = E \cos \frac{\Delta}{2} \text{ or } M = R \left(1 - \cos \frac{\Delta}{2}\right)$$

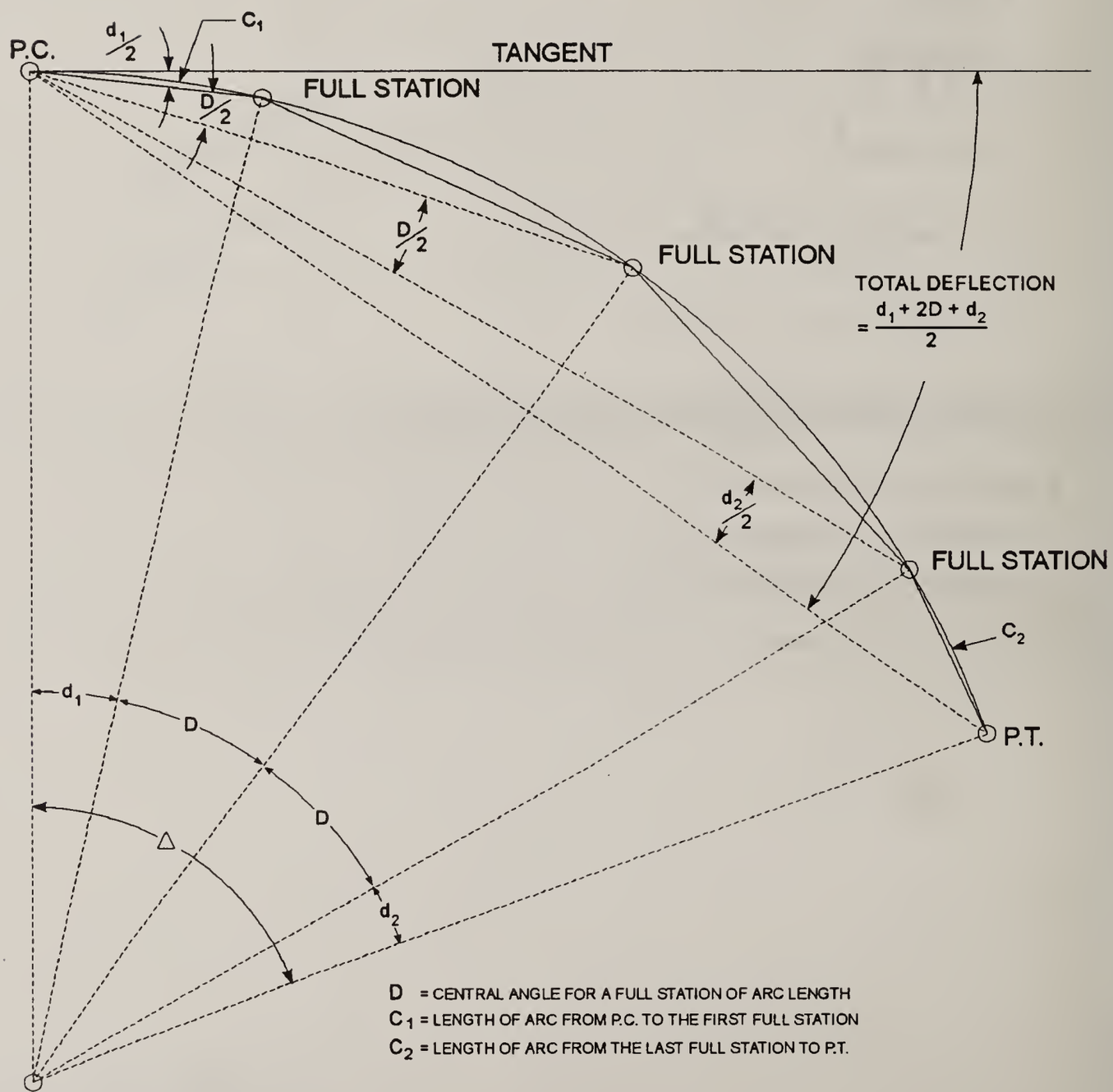
Length of curve, L, $= \frac{100\ \Delta}{D}$ when Δ and D are in minutes

Locating the P. C. and P. T.

Station of P. C. = Station of P. I. – T

Station of P. T. = Station of P. C. + L

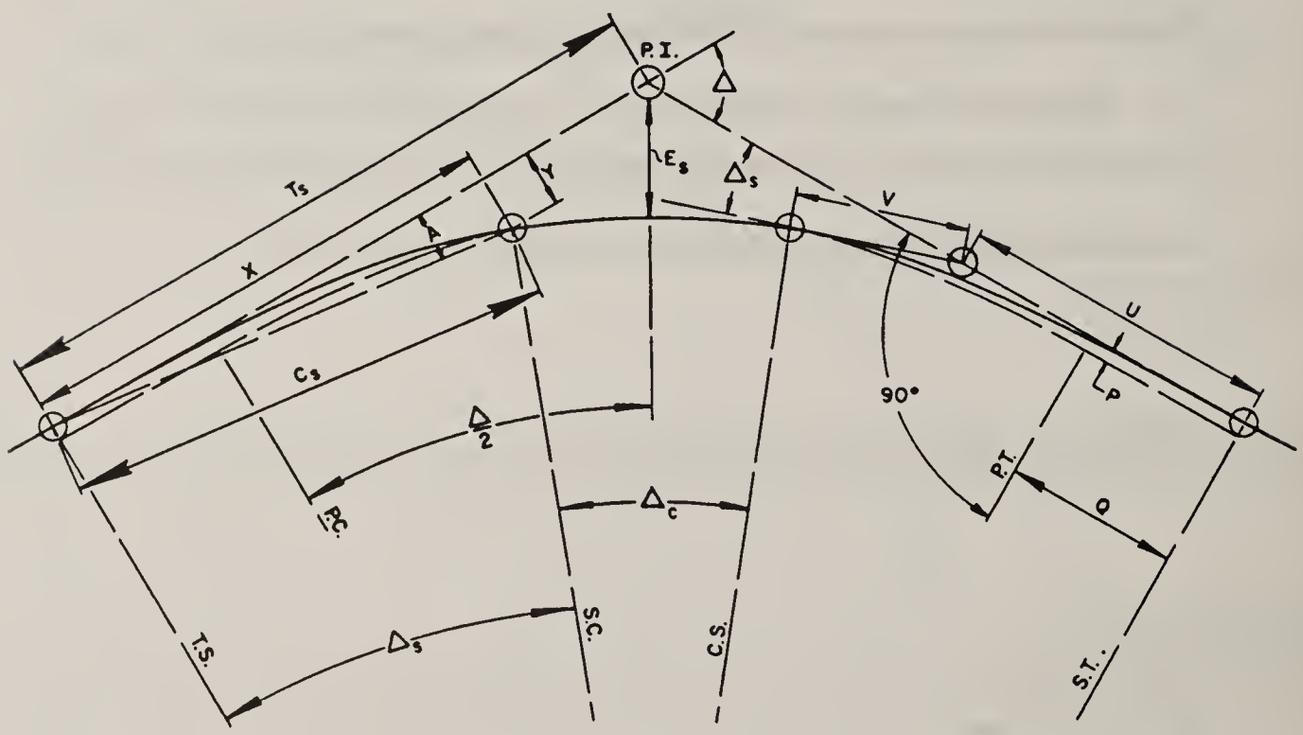
Simple Curve Computation by Deflection Angle



1. Get the P. C. and P. T. stations and the value of D in decimals of a degree, by using the general formulas for circular curves, from the plans, or computer run.
2. The chord for any arc length: 2 R sin (deflection angle)
3. The deflection angles in degrees, for full station arc length equals $\frac{D}{2}$.
4. The deflection angle, in decimal degrees, for any arc length: 0.005 D (arc length)
5. A running total of station to station deflections gives the total deflection angle from the P. C.

Computation Check: The total deflection angle to the P. T. must equal $\frac{\Delta}{2}$

Spiral Curve Transitions



L_S = Length of spiral
D = Degree of curvature of the circular curve
T_S = Tangent distance
Δ = Deflection angle between the tangents
Δ_S = Spiral angle
Δ_C = Central angle between the S. C. and C. S.
E_S = External distance
C_S = Long chord
U = Long tangent
V = Short tangent

X = Spiral coordinate (Abscissa)
Y = Spiral coordinate (Ordinate)
Q = Simple curve coordinate (Abscissa)
P = Simple curve coordinate (Ordinate)
Δ = Deflection angle of spiral curve
K = Constant of increasing curvature
T. S. = Tangent to spiral
S. C. = Spiral to curve
C. S. = Curve to spiral
S. T. = Spiral to tangent

Spiral Curve Formulas

$$\Delta_S = \frac{D\,L_S}{200} \qquad D = K\,L_S \qquad \Delta_S = \frac{K\,L_S^2}{200}$$

To Calculate Tangent Distances of a Simple Curve with Equal Spirals

$$T_S = (R + P)\tan\frac{\Delta}{2} + Q$$

$$T_S = T + Q + P\tan\frac{\Delta}{2}$$

$$E_S = \frac{(R + P)}{\cos\frac{\Delta}{2}} - R$$

$$E_S = (R + P)\,\text{exsec}\,\frac{\Delta}{2} + P$$

$$E_S = E + \frac{P}{\cos\frac{\Delta}{2}}$$

$$\Delta_C = \Delta - 2\,\Delta_S$$

To Calculate Tangent Distances of a Simple Curve with Unequal Spirals

$$T_{S1} = \frac{(R + P)_2}{\sin\Delta} - (R + P)_1 \cot\Delta + Q_1$$

$$T_{S2} = \frac{(R + P)_1}{\sin\Delta} - (R + P)_2 \cot\Delta + Q_2$$

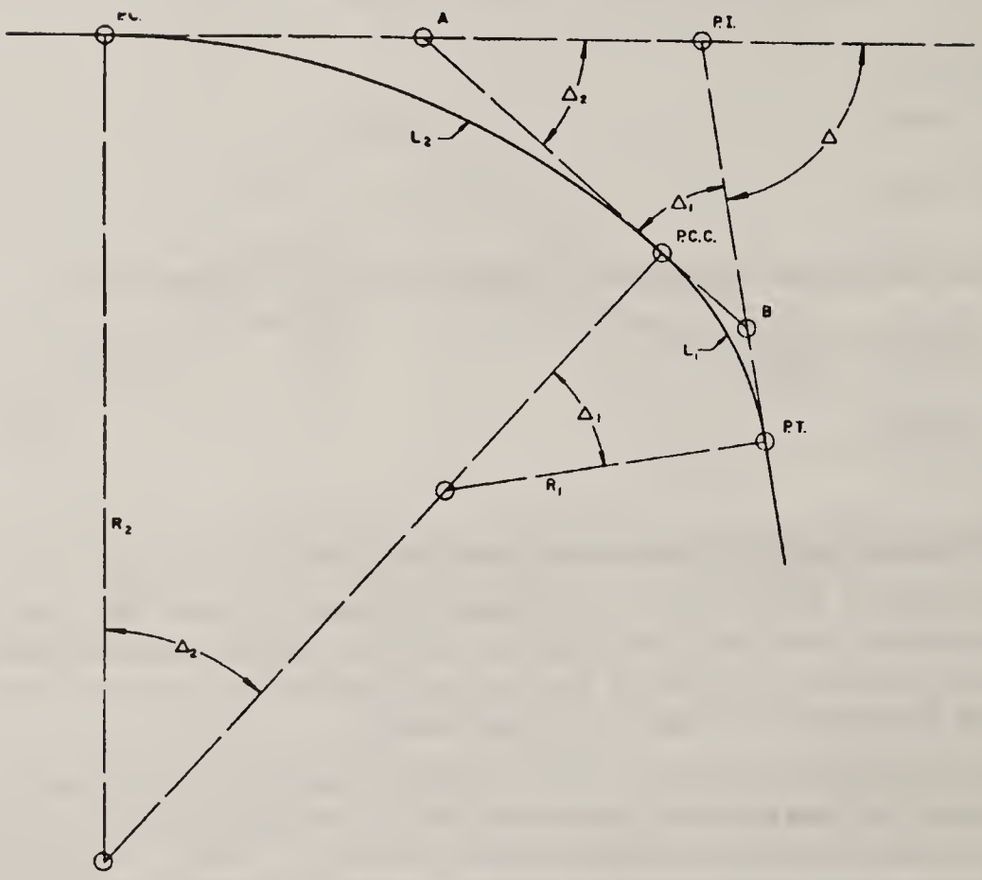
For Deflection Angles to Intermediate Points on Spiral:

A (in minutes) = 10 K S^2, where S = distance in stations to point. This value may have to be adjusted downward. Note that the one-tenth minutes of the tabulated defection angles form a wave-like pattern (equivalent to the above formula) until they fall off near the bottom of the table. Adjustments for intermediate points may be interpolated.

To set stakes with the instrument, set up at a point on the spiral to take advantage of the fact that the spiral is laid out on a system of coordinates. First, set the instrument plate at zero parallel to the tangent of the spiral. This is done by sighting back on the T. S. with "A" for the instrument set-up point on the plates; or by bringing the instrument tangent to the curve with Δ_S for the instrument set-up point on the plates. Then the difference between coordinates of points to be set and the instrument is the deflection angle:

$$\text{Deflection angle} = \tan^{-1}\frac{Y_1 - Y_0}{X_1 - X_0}$$

Compound Curve Computations



Given Δ, R_1, R_2, L_1, L_2 $\qquad \Delta = \Delta_1 + \Delta_2$

Distance to "A" from P. C. equals $R_2 \tan \frac{\Delta_2}{2}$

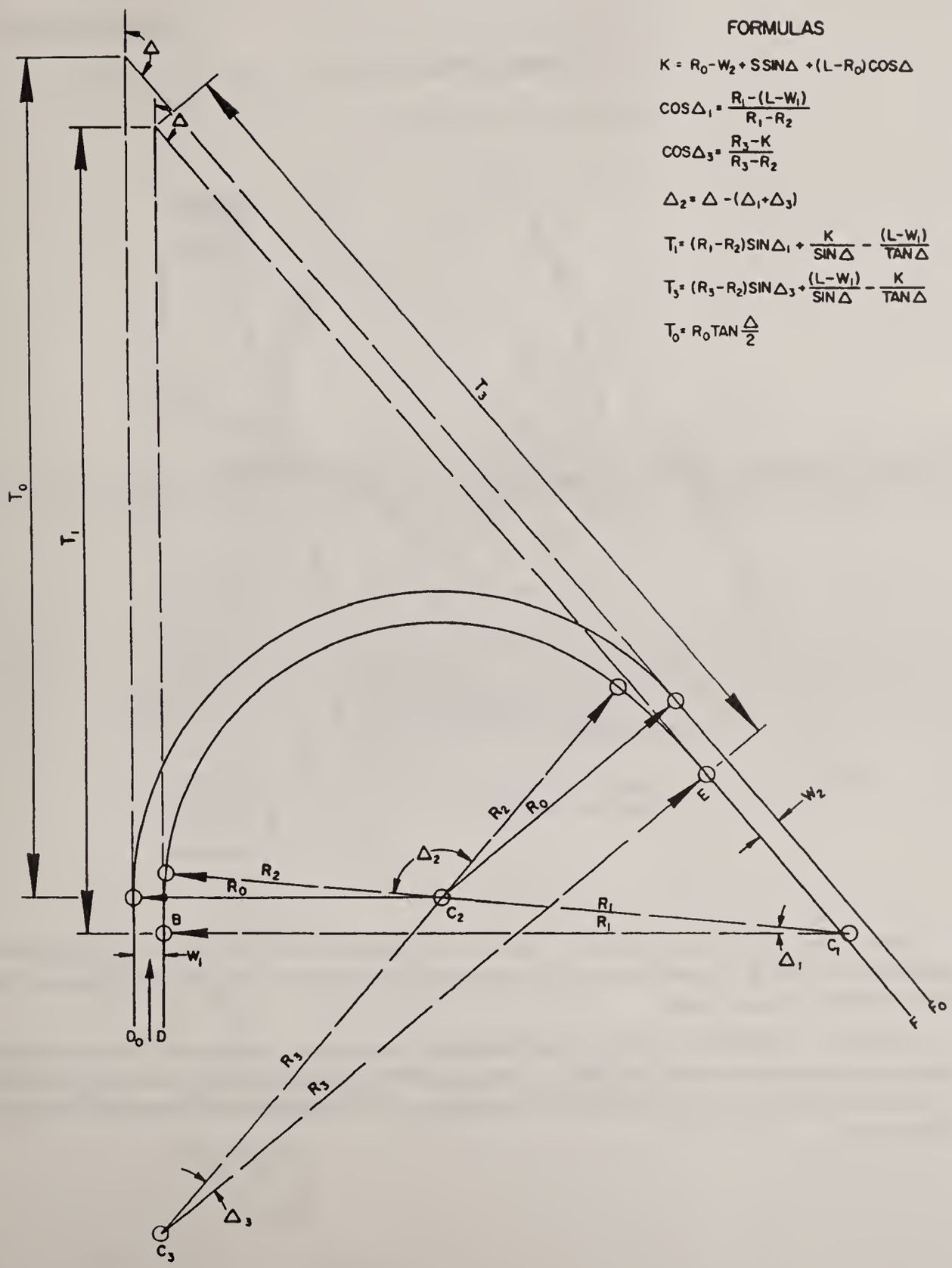
Distance to "B" from P. T. equals $R_1 \tan \frac{\Delta_1}{2}$

Curve is laid out as two adjacent simple curves: one having a radius "R_2" with its P. I. at "A" and the other having a radius of "R_1" with its P. I. at "B."

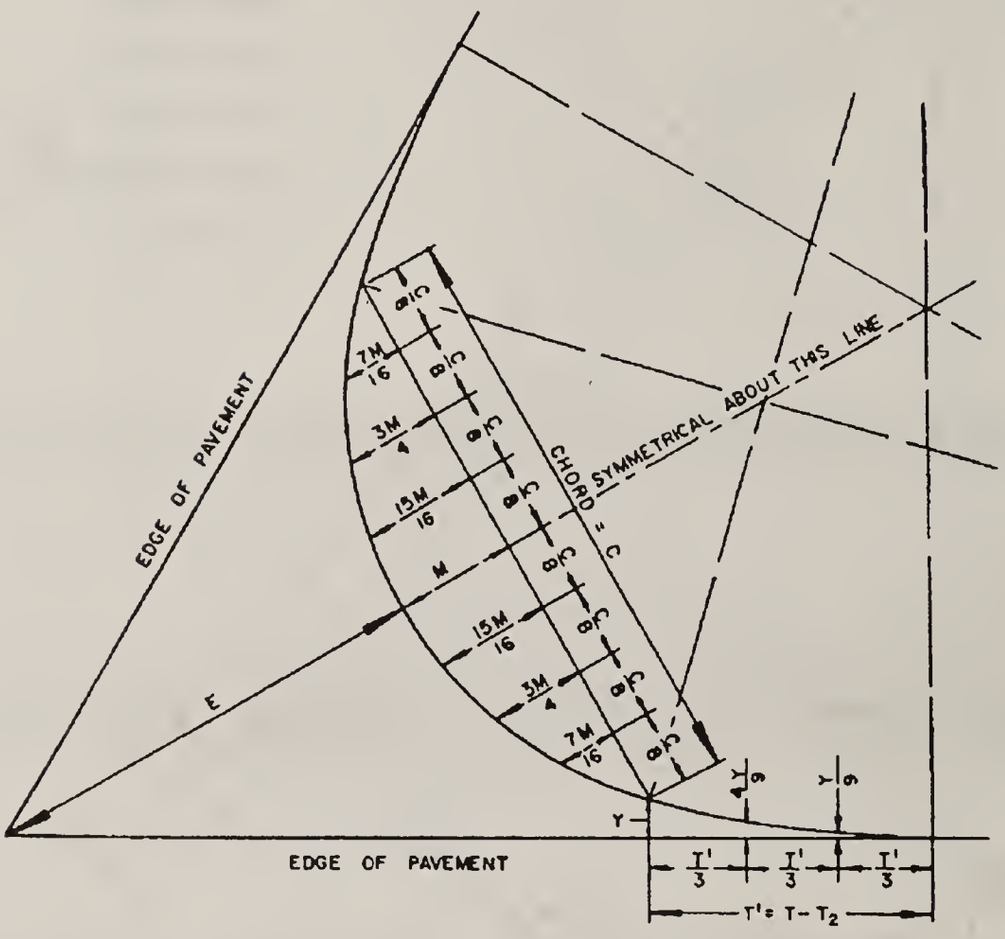
On open highways, the ratio $\frac{R_2}{R_1}$ should not exceed one and one-half $\left(1\,\frac{1}{2}\right)$.

On intersection curves, the ratio $\frac{R_2}{R_1}$ should not exceed two (2).

For sharper curves, use a three-center curve or spiral.


FORMULAS
$K = R_0 - W_2 + S\sin\Delta + (L - R_0)\cos\Delta$
$\cos\Delta_1 = \frac{R_1 - (L - W_1)}{R_1 - R_2}$
$\cos\Delta_3 = \frac{R_3 - K}{R_3 - R_2}$
$\Delta_2 = \Delta - (\Delta_1 + \Delta_3)$
$T_1 = (R_1 - R_2)\sin\Delta_1 + \frac{K}{\sin\Delta} - \frac{(L - W_1)}{\tan\Delta}$
$T_3 = (R_3 - R_2)\sin\Delta_3 + \frac{(L - W_1)}{\sin\Delta} - \frac{K}{\tan\Delta}$
$T_0 = R_0 \tan\frac{\Delta}{2}$
Δ
Δ
T_0
T_1
T_3
R_2
R_0
R_2
R_0
Δ_2
R_1
R_1
C_2
C_1
C_3
B
W_1
W_2
E
Δ_1
Δ_3
R_3
R_3
O_0
D
T_0

Three-Center Curves

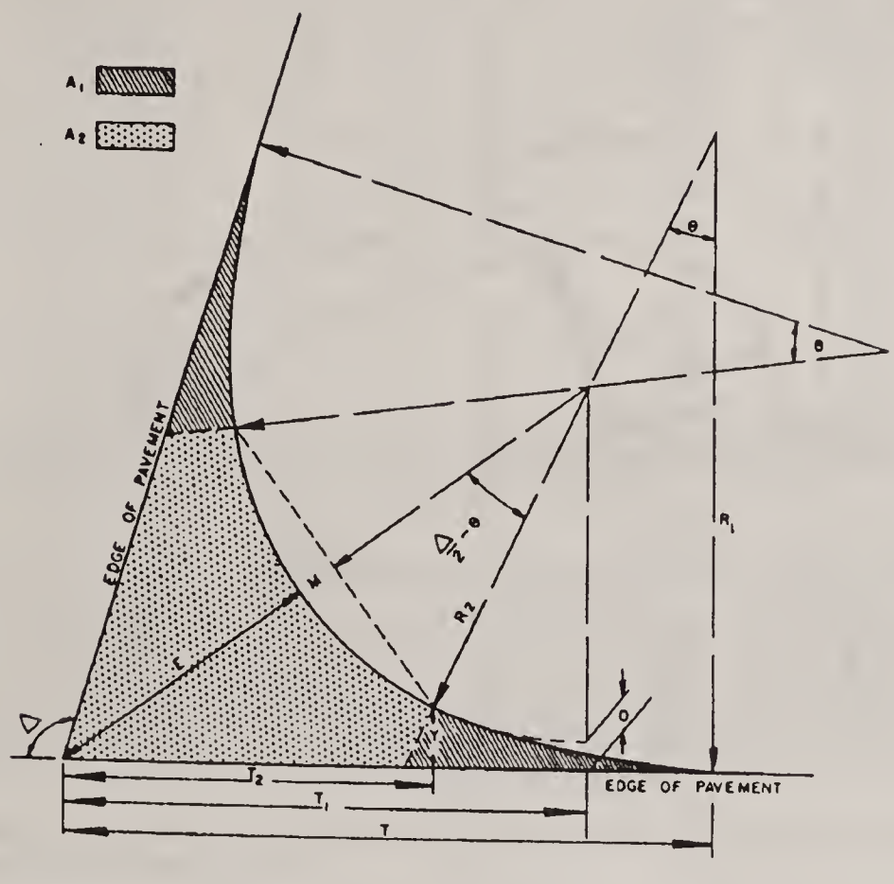


When curve centers are inaccessible, the use of tangent offsets for the long radius curve is suggested for staking 3-center curves. The curves are parabolic but any deviation from a circular curve is within tolerable limits.

The chord is determined by staking out the points of compound curvature and then measuring the distance between these two points. The mid-ordinate "M" is determined by subtracting the external "E" from the distance between the point of intersection of the two edges of pavement and mid-point on the chord.

Formulas Used

Given Δ, O, R_1 and R_2
To find T, T_1, T_2, E, M, θ, Y, and area external to compound curve



$$T_1 = (R_2 + O) \tan \frac{\Delta}{2}$$

$$T = T_1 + (R_1 - R_2) \sin \theta$$

$$T_2 = T_1 - R_2 \sin \theta$$

$$E = \frac{R_2 + O}{\cos \frac{\Delta}{2}} - R_2$$

$$M = R_2 - \left[R_2 \cos \left(\frac{\Delta}{2} - \theta\right)\right]$$

$$\theta = \cos^{-1}\left(\frac{R_1 - R_2 - O}{R_1 - R_2}\right)$$

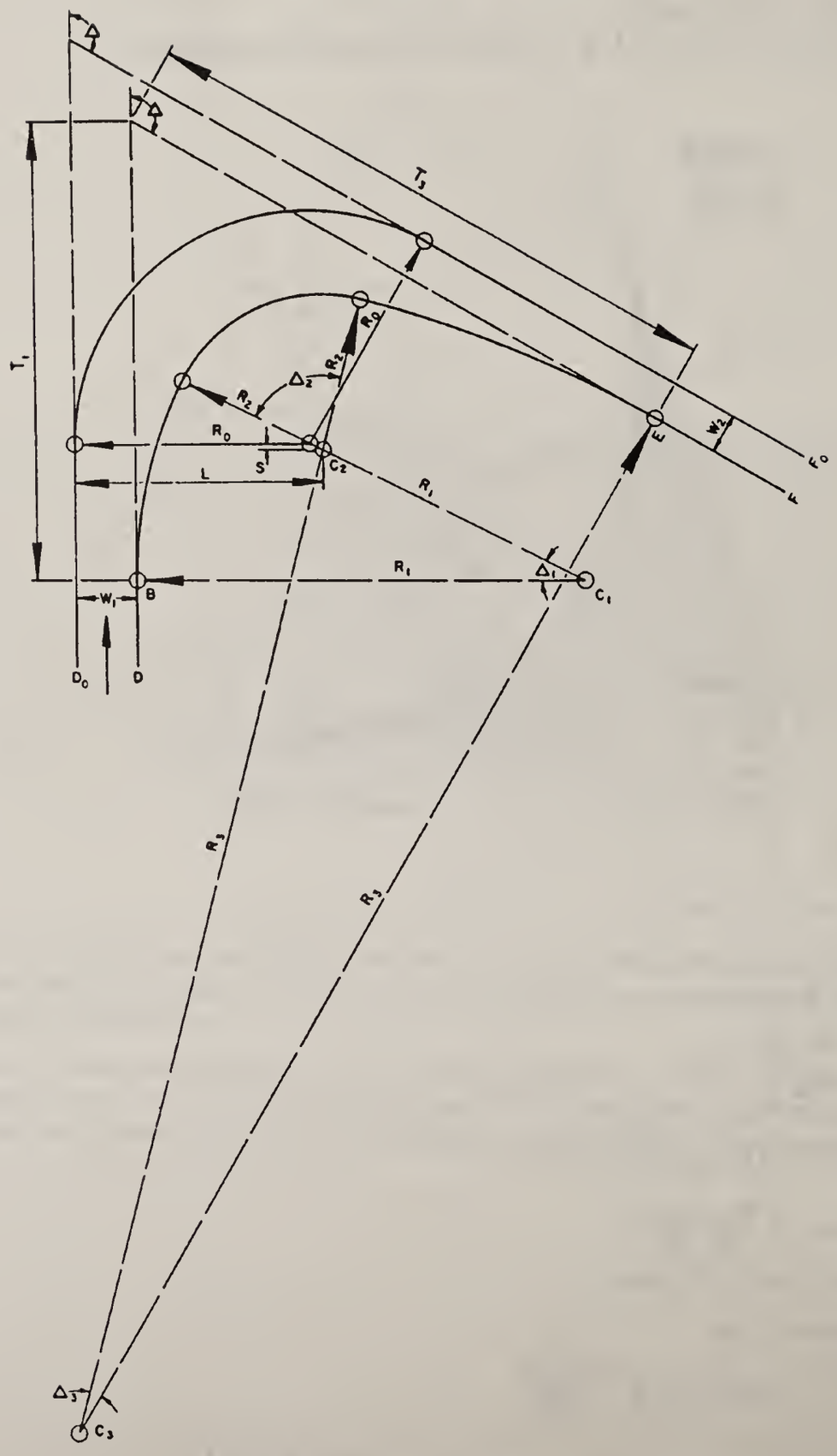
$$Y = (R_2 + O) - R_2 \cos \theta$$

$$\text{Area} = A_1 + A_2$$

$$A_1 = R_1^2 \tan \theta - \frac{\pi R_1^2 \theta}{180}$$

$$A_2 = (R_2 + O)[T1 - (R_2 + O) \tan \theta] - \frac{\pi R_2^2 \left(\frac{\Delta}{2} - \theta\right)}{180}$$

Short Radius Turns



Three-Center Curves and Offsets						
Radius of Outside Edge	Range of Central Angles	Three-Center Compound Curves for Inside Lane Edge				
R_0	Δ	R_1	R_2	R_3	L ⑤	S ⑥
Feet	Degrees	Feet	Feet	Feet	Feet	Feet
② 50	60 to 90 ①	180	45	250	59	15
	91 to 180	120	30	200	48	4.5
	Over 180	80	25	200	50	0
60	60 to 90 ①	120	55	300	69	13.5
	91 to 210	120	40	300	58.5	1.5
	Over 210	80	38	300	60	0
67	60 to 90 ①	120	60	300	74	10
	91 to 180	120	49	300	66	2.5
	Over 180	100	46	300	67	0
75	40 to 59	200	90	300	104	17
	60 to 210	120	57	300	74	1.5
	Over 210	120	55	300	75	0
100	0 to 30	220	③			
	31 to 60	200	90	400	104	5.5
	Over 60	120	83	400	100	0
150	0 to 25	300	③			
	Over 25	300	135	400	150	0
④ 200	0 to 20	400	③			
	Over 20	400	186	400	200	0

① Radii of less than 75 feet for angles of less than 60°, or less than 100 feet for angles less than 40°, are not recommended because of short lengths.

② A 50-foot radius will allow for practically no initial speed of large vehicles. This set of figures for use in critical locations only.

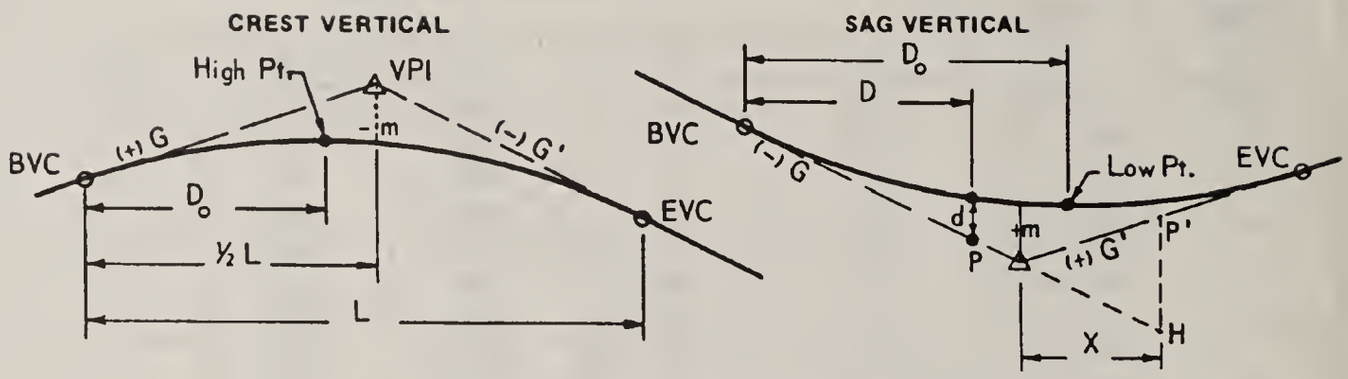
③ Single circular curve of radius R.

④ For any radius between 200 and 500 feet, use concentric curves, inside radius 14 feet less than outside radius, with circular transition curves of twice the central radius.

⑤ When "W1" > "W2," add difference to tabular value of "L."

⑥ When "W2" > "W1," add difference to tabular value of "S."

Parabolic Vertical Curves



Terminology

L = Length of curve, in stations.
G & G′ = Grade rates, in percentages (not decimals), with proper signs.
m = Middle ordinate, in feet.
d = Correction with proper sign from grade line to curve, in feet.
S = Slope, in percentage, of the tangent to the curve at any point on the curve.
X = Distance, in feet, from P′ to VPI.
H = Elevation of Point H, which is on grade "G" produced.
P & P′ = Elevations on respective grades.
D_0 = Distance, in stations, to low or high point from BVC or EVC.
D = Distance, in stations, from BVC or EVC to any point on the curve.

Formulas

$$m = \frac{(G' - G)\,L}{8}, \text{ or}$$

$$= {}^{1/2}\left(\frac{(\text{BVC el.} + \text{EVC el.})}{2} - \text{VPI el.}\right)$$

$$d = \frac{m\,D^2}{(L/2)^2} = \frac{4\,m\,D^2}{L^2}, \text{ or}$$

$$= \frac{D^2\,(G' - G)}{2\,L}$$

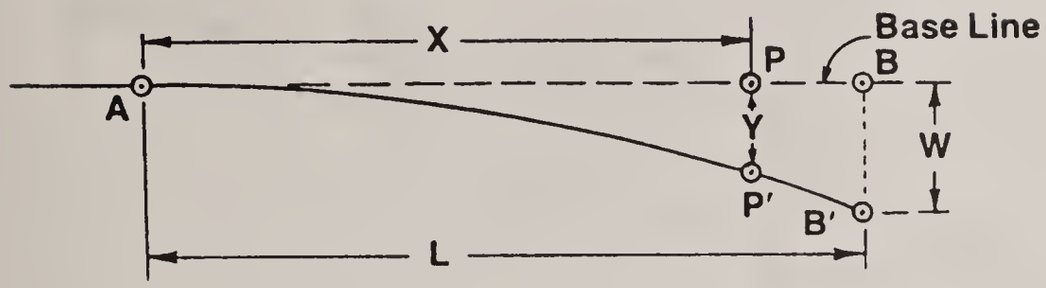
$$X = \frac{100\,(H - P')}{(G - G')}$$

$$S = G - \frac{D\,(G - G')}{L}$$

$$Do = \frac{L\,G}{G - G'}$$

Parabolic Curb Flares

Terminology and Formula



L = Length of flare, in feet
W = Maximum offset, in feet
X = Distance along base line, in feet

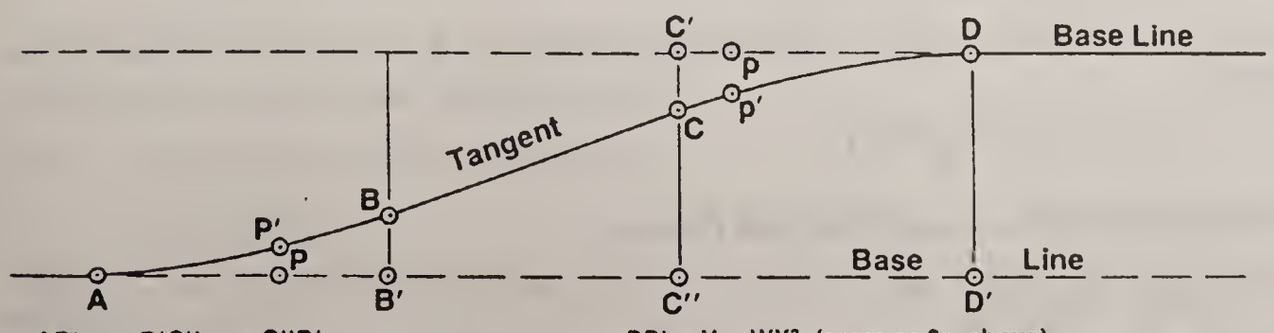
PP' = Y = Offset from base line, in feet.

$$Y = \frac{WX^2}{L^2}$$

Curb Flares Commonly Used

Offsets for Given "X" Values: ("W" is shown in bold boxes.)																
X	10	15	20	25	30	40	45	50	60	70	75	80	90	100	110	120
L						1:5 Flare										
25	0.80	1.80	3.20	**5.00**												
50	0.40		1.60		3.60	6.40		10.00								
						1:10 Flare										
50	0.20		0.80		1.80	3.20		5.00								
100	0.10		0.40		0.90	1.60		2.50	3.60	4.90		6.40	8.10	**10.00**		
						1:15 Flare										
45	0.15		0.59		1.33	2.37	3.00									
75	0.09		0.36		0.80	1.42		2.22	3.20	4.36	5.00					
90	0.07		0.30		0.67	1.19		1.85	2.67	3.63		4.74	**6.00**			
120	0.06		0.22		0.50	0.89		1.39	2.00	2.72		3.56	4.50	5.56	6.72	8.00

Parabolic Tapers

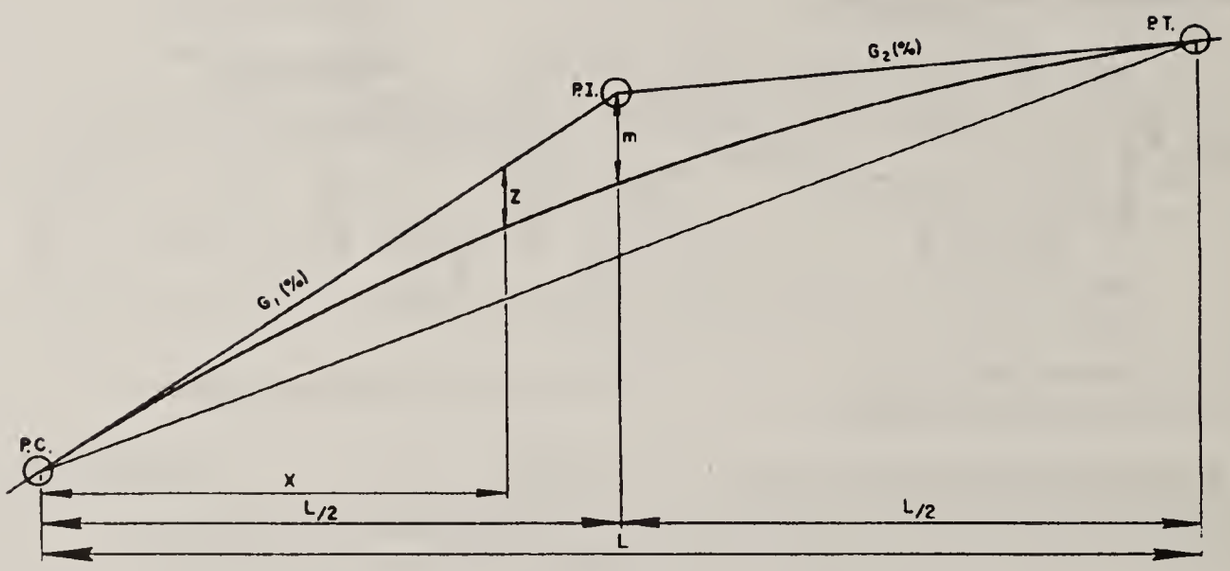


AB' = B'C'' = C''D'
BB' = CC' = ¼DD'

$PP' = Y = \frac{WX^2}{L^2}$; (same as 3a, above)

where, AP or DP = X; AB' or DC' = L
BB' or CC' = W

Symmetrical Vertical Curves



m = Mid-ordinate, in feet
Z = Any tangent offset, in feet
L = Horizontal length of vertical curve, in stations
X = Horizontal distance from P. C. or P. T. to any ordinate "Z," in stations
G_1 & G_2 = Rates of grade, expressed algebraically, as a percentage

All expressions to be calculated algebraically.

Elevation of P. I. = Elevation of P. C. + $G_1 \frac{L}{2}$

Elevation of P. T. = Elevation of P. C. + $(G_1 + G_2)\frac{L}{2}$

$$m = \frac{(G_2 - G_1)\,L}{8} = \frac{1}{2}\left(\frac{\text{Elev. of P.C. + Elev. of P.T.}}{2} - \text{Elev. of P.I.}\right)$$

For offset "Z" at distance "X" from P. C. or P. T.:

$$Z = m\left(\frac{X}{L/2}\right)^2 \text{ or } Z = \frac{X^2\,(G_2 - G_1)}{2L}$$

For slope "S" of a line tangent to any point on the vertical curve at an "X" distance measured from the P. C.:

$$S = G1 - \left[X\left(\frac{G_1 - G_2}{L}\right)\right]$$

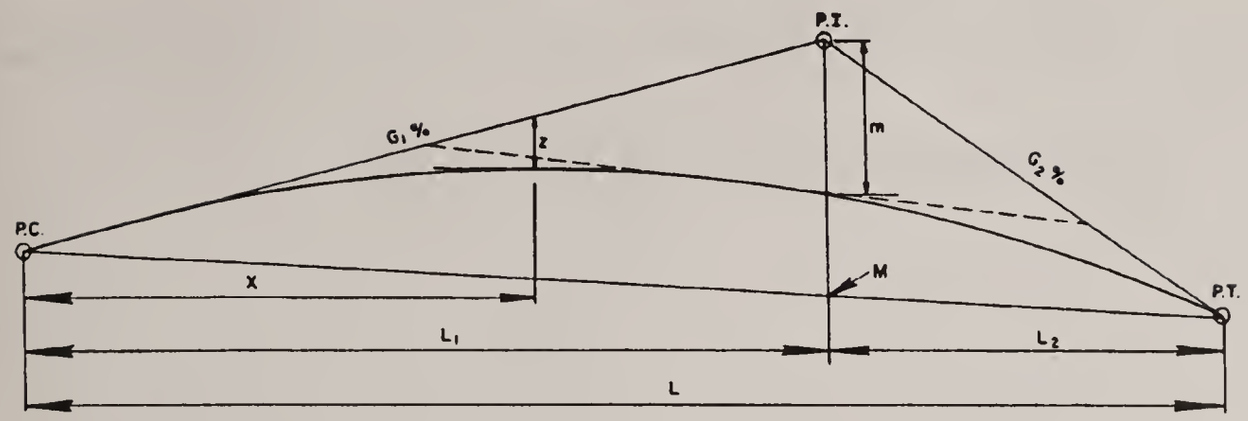
Calculating High or Low Point on Curve

$$XT = \frac{L\,G}{G_1 - G_2}$$

Where "X_T" equals the horizontal distance, in stations, from the P. C. to the high or low point on the curve.

Elevation of high or low point on curve equals: Elevation of P. C. $- \frac{1}{2}\left(\frac{L\,G_1^2}{G_2 - G_1}\right)$

Unsymmetrical Vertical Curves



M = Theoretical point on P. I. station
m = Offset from the P. I. to the curve, in feet
Z = Any tangent offset, in feet
L = Horizontal length of vertical curve, in stations
L1 = Horizontal distance from P. C. to P. I., in stations
L2 = Horizontal distance from P. T. to P. I., in stations
X = Horizontal distance from P. C. or P. T. to any ordinate "Z," in stations
G_1 & G_2 = Rates of grade, expressed algebraically in percentages

All expressions to be calculated algebraically.

Elevation of P. I. = Elevation of P. C. + $G_1 L_1$
Elevation of P. T. = Elevation of P. C. + $G_1 L_1 + G_2 L_2$

$$\text{Elevation of M} = \text{Elevation of P. C.} + \frac{L_1}{L}(G_1 L_1 + G_2 L_2)$$

$$m = \frac{L_1 L_2}{2L}(G_2 - G_1) = \frac{\text{Elev. of M - Elev. of P.I.}}{2}$$

For offset "Z" at distance "X" from P. C.:

$$Z = m\left(\frac{X}{L_1}\right)^2$$

For offset "Z" at distance "X" from P. T.:

$$Z = m\left(\frac{X}{L_2}\right)^2$$

Calculating High or Low Point on Curve

If high or low point occurs on left portion of curve:

$$X_T = \frac{L_1}{L_2}\left(\frac{G_1 L}{G_1 - G_2}\right)$$

Where "X_T" equals the horizontal distance from the P. C. to the high or low point on the curve in stations.

$$\text{Elevation of this point} = \text{Elev. of P. C.} - \frac{1}{2}\left(\frac{L_1}{L_2}\right)\left(\frac{L\,G_1^2}{G_2 - G_1}\right)$$

If high or low point occurs on the right portion of the curve:

$$X_T = \frac{L_2}{L_1}\left(\frac{G_2\,L}{G_2 - G_1}\right)$$

Where "X_T" equals the horizontal distance from the P. T. to the high or low point on the curve in stations.

$$\text{Elevation of this point} = \text{Elev. of P. T.} - \frac{1}{2}\left(\frac{L_2}{L_1}\right)\left(\frac{L\,G_2^2}{G_2 - G_1}\right)$$

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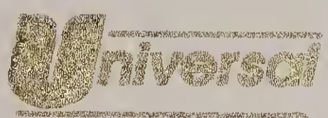

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